ANCIENT SYSTEM OF IRRIGATION IN BENGAL

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LECTURES

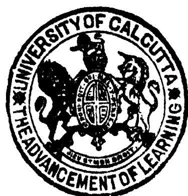
ON THE

ANCIENT SYSTEM OF IRRIGATION IN BENGAL

AND ITS APPLICATION TO MODERN PROBLEMS

BY

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PUBLISHED BY THE
UNIVERSITY OF CALCUTTA
1930

PRINTED BY BHUPENDRALAL BANERJI
AT THE CALCUTTA UNIVERSITY PRESS, SENATE HOUSE, CALCUTTA

Reg. No. 532B.—June, 1930. —A.

CONTENTS

I

The "Overflow Irrigation" of Bengal

1. " O thou River, who didst bring forth al things ; when the great gods dug thee out, they se prosperity upon thy banks." Such was the invocation of some old world Babylonian seer to the River Euphrates ; and this invocation might be made with assurance in this our modern world to al those rivers whose turbid flood waters are made use of for pouring health and wealth over the lands on their banks. Irrigation is the oldest applied science in the world ; and the most ancient centres of irrigation were the seats of the oldest civilizations, because healthy irrigation on an extended scale was and is the great school of civilization. Successful irrigation on extensive systems was impossible unless men were ready to work in accord with each other, to respect each other's rights, to combine together and obey their own regulations, and finally to exercise their intelligence to the full, and so live in healthy surroundings, free from danger, and with

plenty to eat. It was to the difficulties of the problems which faced the first Bengal irrigators and to their successful overcoming of them that I attribute your undoubted brain power and your passion for co-operation; and long may God give it to you to enjoy both.

2. Born in India over 77 years ago in a tent or an irrigation canal, I have spent my whole life on irrigation works and in irrigated countries, and I deem it a high honour to give you of my very best to help to bring back your ancient irrigation to its palmy days, before the break-up of the Mogul Empire in the 18th century struck it its first severe blow. And it is with a double pleasure that I give of my very best, for I am firmly convinced that the only means by which cheap food and necessaries and healthy surroundings can be secured for the many millions of your poor, are (1) the use of the muddy waters of your rivers to irrigate your fields, and (2) the wise regulation of the Hooghly to keep your harbours abreast of the shipping requirements of the day. These two objectives are bound together in one sheaf, and you will learn much about them. Keep them always before you.

3. Some 6,000 years ago the Egyptians introduced their system of basin irrigation into the Nile

Valley by digging canals which are in use to-day and leading the turbid waters of the Nile into embanked basins which are working to-day. The turbid waters of the Nile floods entered these basins and covered the land with their rich deposit. As the Nile ebbed, the husbandmen followed the retreating water and scattered their grain over the slime and ooze. No further irrigation was required for the crops were all winter crops. Contemporaneously with them, the Babylonians began their system of perennial irrigation in the joint delta of the Euphrates and Tigris. It has been my privilege to study both these systems on the ground, to resuscitate the great reservoir of the Pharaohs of the 12th dynasty of 4,000 years ago, and to project and begin the resuscitation of the ancient reservoir of the Babylonian kings of more than 4,000 years ago. This I should have finished if the Wali of Bagdad had not spent on the army the money allotted for the work. To-day I am privileged to show you what was the system of "overflow irrigation" evolved by the rulers of ancient Bengal some 3,000 years ago and to let you see how such irrigation can be reintroduced in the Ganges and Damodar deltas, and bring in again the health and wealth which Central and Western Bengal once enjoyed. The

plains of Central Bengal will not only be employed to have the wealth of Eastern Bengal transported across them, but will be again pouring their own wealth into the capital of their country.

4. The delta of the Ganges is no rainless land like Egypt, nor is it a dry, thirsty land like Babylonia. It enjoys a rainfall of from 50 to 60 inches just when all the rivers are in flood; and it was to make full use of the rich waters of the Ganges and Damodar floods and the abundant but poor water of the monsoon rainfall that some early Bengal king thought out and put in practice the system of "overflow irrigation" of the Ganges and Damodar deltas which insured health and wealth to Bengal for very many hundreds of years. This system is as perfectly suited to meet the special needs of Bengal as "basin irrigation" suits those of Egypt or "perennial irrigation" meets those of Babylonia.

5. Bengal with its heavy monsoon rainfall between June and October is marked out for rice cultivation. Such cultivation is possible without flood irrigation from the rivers; but, if dependent altogether on rainfall, it impoverishes the soil and can produce malaria though it cannot combat it. Now these ancient kings and peoples came from the north-west and must have had with them many ex-

perts from the Euphrates and the Nile; for the irrigation of Babylonia and Egypt was not practised in a corner. The whole world knew about it. The genius of Bhagirath showed itself in the way he decided to mingle in the fields of standing rice, the fertilising and health-giving waters of the rivers in flood with the poor water of the monsoon rainfall. This was possible because the river floods and the monsoon rainfall came together. The distinguishing feature of the irrigation was that:—

(1) The canals were broad and shallow carrying the crest waters of the river floods, rich in fine clay and free from coarse sand.

(2) The canals were long and continuous and fairly parallel to each other, and at the right distance from each other for purposes of irrigation.

(3) The irrigation was performed by cuts in the banks of the canals, which were closed when the flood was over. These artificial cuts are today called "Kanwas" in Bhagalpur. This is a very interesting word of which you will hear again.

It has a history. (You see these distinguishing features wherever you see the handiwork of the kings of Bengal. To the basin irrigation of Egypt cross banks are a necessity. To the "overflow irrigation" of Bengal cross banks are an abomination, unless they are freely pierced by openings.)

6. The procedure at the time of irrigation must have been as follows :—Once the engineers made the breaches, the water was handed over to the local boards, and the local boards working through the peasantry were expected to see to it that the water reached every field. Water cannot be left to itself; it goes along the line of least resistance, over-irrigates in one place and does not irrigate at all in another. No suppression of malaria is possible on such lines, as mosquitoes travel. Nor can there be any enriching of the soil. But with properly controlled overflow irrigation they had both. They had a supply of river water far in excess of actual requirements, but they needed this excess supply to insure the irrigation of every individual field. The following of such water from

field to field and the becoming as much interested in one's neighbour's property as in one's own (for they could not separate their neighbour's interests from their own) elevated everyone engaged in it. Such work was a better field for developing character than any school. I have purposely put these facts in detail before you, to increase your interest in this past history of your ancient irrigation, and to bring its realities home to you. Your inherited love of co-operation did not descend on you from the clouds; it came with the distribution of the muddy waters of your "overflow canals." It will stand you in good stead when "overflow irrigation" is re-introduced.

7. I have said that the "overflow irrigation" of the ancient kings was given to the fields through artificial cuts in the banks, which cuts are to-day known in the neighbouring district of Bhagalpur by the name of "Kanwa." This is one of thirty irrigation terms used in the *District Gazetteer* of Bhagalpur of which all the terms are ancient words except one. The single exception is "sulus" or "sluice." The word "Kanwa" is derived from "Kan" an old Persian or Arabic word, meaning "to dig." It was undoubtedly taken from irrigated Babylonia which lay between Arabia and

Persia. These cuts, when made in the main river banks as heads for " overflow canals," were called names connected with the word " Kan." Thus in the Damodar area we have a number of channels which are called " Kana Nuddee," while in Hooghly we have three separate "Kana Nuddees," as well as " Kana Damodar," " Kunti Nuddee " and " Kintool Nuddee," all old artificial works. Then there are several " Kani Nuddees " and a " Kana Dalkishar;" the last of which cannot possibly be anything except a cut to carry very muddy water. These canals bore these names when they were living streams full of vitality; and though to-day they are nothing but long chains of stagnant pools of water, breeding malaria and poverty, they are still called " Kanas " and " Kanis." And because there is another word " Kana " meaning " blind " pessimists have jumped to the conclusion that these " Kanas " are " blind rivers." They have acted in the same way in Central Bengal; the pessimists have called all the old canals in Central Bengal " dead rivers." As a matter of fact these "blind" and "dead" canals are the only seeing and living irrigation works in the whole of Bengal. They have vision; they have a future. They are neither blind nor dead, but they have a potency of life in them;

and, like those fabled dragon's teeth, when sown up and down, they will one day spring up full-grown men.

8. We have so far spoken principally of the agricultural value of muddy flood water, we shall now say something about its value from the point of view of public health. Dr. Bentley, Director of Public Health in Bengal, stands before the world as the apostle of the prevention of malaria by irrigation with muddy flood water, and when something is done in Bengal, Bengal will owe more to him than to any human being alive to-day. He shows in his striking book "Malaria and Agriculture" (Bengal Secretariat Book Depôt, Calcutta, 1925: price Rs. 2-2 or 4*s*.) that the increase of irrigation with muddy flood water and the decrease of malaria are one and the same thing in Bengal, as they are in all deltas. I have never read a more convincing work in my life. And you will see that the history of the "overflow irrigation" of Bengal, which I am now entering upon, will bear out every word of what he has written—Central and Western Bengal owed their health and their wealth entirely to the "overflow irrigation" from the ancient canals of the Ganges-Damodar delta, and, if Dr. Bentley had been listened to these last ten years, they would

have been owing it to-day. I heard of his gallant fight for flood irrigation eight years ago and am sorry indeed I only came here in the spring of 1928, and that at the invitation of Miss MacLeod and her friends in England who love to work with the poor. God bless them and their work.

9. The *Mahabharata* tells us that as Bhagirath followed by Ganga descended the Ganges valley, near the head of the Delta, Bhagirath rested to eat his meal; and Ganga, hearing the sound of Padmavati's shell, thought it was Bhagirath's and followed her in her eastern course down the Padma. It was then that Bhagirath sounded his shell and Ganga recognised her mistake. She retraced her steps and went southwards. Following the genius of your country, your ancient writers described the physical facts they were writing about in spiritual language, but the facts were there all the same. Every canal which went southwards, whether it has become a river like the Bhagirathi, or remained a canal like the Mathabhanga, was originally a canal. They were lined out and dug fairly parallel to each other. They were spaced apart and placed just about the distance apart that canals should be placed. I remember quite well when I began to line out a system of canals for the irrigation of the country,

I was astonished to find everywhere that a so-called "dead river" on the map was just where a canal should be placed. Leaving out the numerous cross cuts with which 200 years of neglect have covered the map, and which represent scoured out channels for the "Kanwas" which were always left open at the same spots and not annually moved as they should have been, the long continued parallel alignments of the main canals can be readily seen by a practised eye. They are very different to the tangled, meaningless mass of waterways which are to be seen south-east of Faridpur, where we have nature's undirected handiwork. The Mathabhanga is the true ridge of the country, and from it were led off so many canals that the Mathabhanga itself dwindled in size as it continued its course, and hence its name of Mathabhanga or "broken-headed."

10. It must be always kept in mind that ordinary irrigation canals carry nothing but river water from start to finish, but the "overflow canals" of Bengal worked under different conditions. The irrigation of the country was done principally by rainfall and the river water was used to manure the rainfall, and kill the mosquitoes or deprive them of their malignity. Such canals were real canals at their heads carrying nothing but river

water; while at their tails they were practically drains carrying little but rain water which had drained through the fields. This matter will assume a great importance when we come to consider the restoration of this ancient irrigation.

11. Now let us turn to the Damodar river. The Damodar is a very ancient river, and the original course of the main stream must have been past Burdwan, Ranaghat, South of Krishnagar, and Jessore, with its delta spread out north and south of this line. All the small rivers coming from the west like the Ajai had also deltas of their own with the main slope from west to east. When at a comparatively recent date, after convulsions in the north which gave birth to the Himalayas, the Ganges came down from the west, it was confined on the north by the hard deposits we see at Rampoor Boalia, the Baral head and the Hardinge Bridge. On the south it was confined by the Damodar delta. It had to go eastwards and south-eastwards, with Ganga following the call of Padmavati's shell, right down to the open water of the Bay. The Ganges, as it flowed on, filled up, with its lighter silt, the valley between the hard northern deposits and the Damodar delta. This is the valley occupied by Murshidabad, Nadia and northern Faridpur, whose

soil in very great part, is composed of the light silt which is so easily eroded, so soon dry, and so desperately in need of irrigation with the clayey water of the surface flow of the Ganges flood. This muddy water is not only needed to renew the fertility of the soil and to combat malaria, but also to arrest the increase of that dangerous Kans grass which, when left alone, is capable of rendering the land quite sterile.

12. When the Bengalis began the physical conquest of the delta, the valley occupied by Murshidabad, Nadia and northern Faridpur had been filled up, and the Ganges could be led southwards if skilfully handled. One of the first great public works appears to have been the taking of the perennial waters of the sacred Ganges to a very sacred shrine on the main stream of the old Damodar, by the Bhagirathi, or the Bhagirathi and the Jelingi. If one reads carefully the account in the *Ramayana* one sees that the reference is to the diversion of a portion of the perennial waters of the Ganges, which 50,000 of the King's subjects could not accomplish, but which Bhagirath, the King's grandson, accomplished by his ingenuity. These spiritual interpretations of physical facts in the old classics are delightful studies. To allow the

perennial supply from the Ganges to be maintained in the Hooghly (as the joint stream of the Bhagirathi and the Jelingi was called below their junction), the Damodar itself had to be controlled. The main stream of the Damodar was closed at the right angular bend, and the whole supply of the river turned down south past Jamalpur, with heavy embankment on its left bank to protect the rich lands of southern Burdwan, Hooghly and Howrah. To irrigate these rich lands, seven canals were dug and the whole seven canals constituted a new delta. These canals or " Kanas " relieved the new Damodar, and between them they disposed of the whole excess supply which passed Burdwan.

13. Let anyone follow the long-continued, well-spaced alignments of these seven canals, of the main canals in Central Bengal, and in the Tanjore delta, and he will not be surprised to learn that history tells us that the Chola Kings of Bengal conquered southern India, became masters of the Tanjore delta, and introduced their system of irrigation there. These Chola Kings were great irrigators of the type of the Pharaohs of the 12th dynasty who made Lake Moeris in the Nile Valley and with their works rivalled the feats of the first dynasty Pharaohs who introduced basin irrigation into the Nile Valley.

14. That the Damodar has been turned out of its delta is confirmed by the fact that in going down the left bank of the Damodar of to-day, one finds oneself, south of Jamalpur, out of the delta of the Damodar, with the river itself up in the air. This is south of the old delta of the Damodar. It is the same to the north of it. As one comes down the Bhagirathi, one finds the river kept from overflowing the country past Berhampur and southwards; but further south the bank ends and there is no need of protection. We are up against the deltas of the Ajai and the ancient Damodar.

15. Let no one imagine that a feat like that of turning the Damodar was beyond the power of a man like Bhagirath. About 6,000 years ago King Menes turned the Nile from the extreme western limit of the valley to the eastern limit to protect the temples of Memphis from the eastern nomads. It was also about 5,000 years ago that some ancient Babylonian king, tradition says Nimrod, turned the Tigris out of its course by a boldly planned work, which stood for 4,000 years until Halaku destroyed it and began the ruin of Babylonia. The old reservoir of the Nile Valley constructed 4,000 years ago was one of the seven wonders of the ancient world. All these ancient irrigators were real giants, and any engineer

from any country in the world is justified in feeling flattered by being in any way connected with the restoration of the great irrigation works of antiquity, whether the works were in Africa or Asia.

16. The " overflow canals " of Bengal fall behind the great irrigation works of other countries in no particular whatever. First of all stands the magnitude of the work. Take the country traversed by these canals on the Ganges and the Damodar, and we have an irrigated area which could not have been under 7,000,000 acres. And then we have canals aligned and designed on the soundest principles, which worked for many hundreds of years and were only dislocated by a generation of civil war and discord. Speaking of these canals, or " dead rivers " as they are called to-day, we may say :

(1) The spacing apart of the canals is just where canals would be placed to-day if there were none already on the ground.

(2) They are fairly parallel and continuous in the direction in which they start, which is absolutely artificial.

(3) They are wide and shallow to carry the beneficial muddy surface waters of the

rivers and avoid the harmful sandy waters of the beds.

(4) The villages are constructed on their banks as villages would naturally be constructed, under the conditions in Bengal, on raised banks.

(5) All the canals were originally dug straight as a matter of course, but their winding courses to-day are a true gauge of the friability of the soil they traverse. Their winding courses along their original alignments are nature's masterful handiwork. No fresh levelling and surveying is required as a rule. The canals need clearing out and embanking with the excavated material. Water ran down them in the past. It will run down them in the future. They are spaced ready for overflow irrigation. All they want are superfluous and redundant bends cut off.

17. We know something about the history of these works. Historians tell us that Northern India was conquerred and settled by Indo-Europeans between B.C. 2000 and 900, and the Epics of the

Mahabharata and *Ramayana* preserve records of their feats, much of it in spiritual language, which we have already reduced in places to concrete physical facts. The irrigation works of Egypt and Babylonia were ancient history in those days. The Chola Kings who lived in Bengal about 2,000 years ago were the heritors of a system of irrigation which they took with them when they conquered the extreme south of the Peninsula and which they introduced into the Tanjore delta. Their handiwork can be seen to-day in Tanjore in working order; and what we see is exactly what we see in Bengal although it is not in working order.

18. In the middle of the seventeenth century A.D., round about 1660, Bernier twice visited Bengal and wrote about what he saw before the break-up of the Mogul Empire and the long continued fight between the Mahrattas and the Afghans had disorganized the ancient "overflow irrigation" of Bengal. In one of his works he says :—

> "The knowledge I have acquired of Bengal in two visits inclines me to believe that it is richer than Egypt. It exports in abundance cottons and silks, rice, sugar and butter. It produces amply for its

own consumption of wheat, vegetables, grains, fowls, ducks and geese. It has immense herds of pigs and flocks of sheep and goats. Fish of every kind it has in profusion. From Rajmahal to the sea is an endless number of canals, cut in bygone ages from the Ganges by immense labour, for navigation and irrigation, while the Indian considers the Ganges water as the best in the world."

19. In 1794, after the Mahratta-Afghan wars had laid their withering hands on the "overflow canals" of the Ganges, a treatise was written by several Englishmen in Calcutta and printed in 1803 and 1806, from which I give a few quotations. These quotations are taken from *Indian Engineering* of 7th July, 1928 :—" In the tract of annual inundation, insulated habitations and fields raised considerably above the level of the country exhibit the effects of patient industry."..." There were dikes to check the inundations" and "reservoirs and dams constructed for irrigation."..." Irrigation is less neglected than facility of transport. In the management of forced rice, dams retain the water on extensive plains, or preserve it in lakes to water

lower lands, as occasion may require. For either purpose much skill is exerted in regulating the supplies of water."..." There are stupendous dikes, not altogether preventing inundation, but checking its sudden excesses," and " dams advantageously constructed assist the cultivation of considerable tracts." The treatise adds that in earlier days things were better, and that reservoirs, water-courses and dikes were in a process of decay rather than in a state of improvement.

20. In 1815 Hamilton passed through Burdwan, Hooghly and Howrah (the original Burdwan raj). Here is a description of this tract by him :— " In productive agricultural value in proportion to its size, in the whole of Hindustan, Burdwan claims first rank and Tanjore second." This is very instructive. Though the Mahratta-Afghan wars had thoroughly disorganized the more difficult irrigation on the Ganges, the easier irrigation on the Damodar had held its own; and here we see the two tracts on the Damodar and in Tanjore both enjoying the " overflow irrigation " of the Bengal Kings, classed as the two most productive tracts in the whole of India.

21. It is evident that by 1815 the zemindars and tenants of Central Bengal had neglected the

clearing of the canals and the repairing of the banks with the silt so cleared, a work known as "pul-bandi," and which in Egypt the forced labour gangs had done for 6,000 years until the English freed the forced labour and did the work by contractors. This negligence began in Bengal in the troublous Mahratta-Afghan wars, and the early English who were traders and sailors knew nothing about irrigation. Seeing many waterways neglected and unused after the wars, they thought the canals (called by them rivers) were only for navigation and they left them alone. This negligence made Central Bengal in 1815 cede the place of honour it held in 1660 in Bernier's day, to Burdwan whose river, the Damodar, was much better placed for irrigation than the Ganges. Decay had begun in Central Bengal, and it began later in Burdwan where the canal clearances were neglected on the canals which took off from the river, and there remained nothing but the filling up of the breaches made in the banks of the Damodar itself. As the uncleaned canals took less and less water, more water remained in the Damodar and it became a menace to the country. The Damodar banks now assumed a fresh importance. These banks were known as "zemindari banks." They were breached by the peasantry when the fear

of an inundation had passed or a breach had occurred elsewhere; and in this way the old canals now called definitely "dead rivers" were filled with water and the country irrigated more or less perfectly. This may well be called "Zemindari bank irrigation."

22. And now the final blow was struck which definitely killed "overflow irrigation" in Bengal. It was imagined by everybody that these "Zemindari banks" were only flood protective works, and that they were kept up solely for that purpose. The "Zemindari bank irrigation," which was practised when the breaches or "Kanwas" were made and the canals or "kanas" were filled with water, was considered as non-existent. The "overflow canals" were called "dead rivers" in places and "drainage lines" in others, but the word "irrigation" was never mentioned. Irrigation still went on, however, because the zemindars and tenants made secret breaches in the banks and irrigated their lands when they could. These breaches were considered by the authorities as breaches made by the uncontrolled floods of the rivers, and the Government set itself to put an end to such discreditable occurrings. It never seems to have struck anybody that the breaches were made secretly by the peasantry for irrigation. And yet it ought to

have been evident that 40 or 50 breaches in a heavily embanked river of inconsiderable length in a single year could not possibly have been made by the river itself; for one or two breaches eased the situation.

23. Pages 164 to 166 of the *Hooghly Gazetteer* are now very instructive reading. A committee in 1846 recommended that the banks of the Damodar be removed and the river be allowed to flow freely down the "overflow canals," which they called "drainage channels" and whose clearance they recommended. Nothing, however, was done, and as the canals were not cleared, the banks of the Damodar remained. The banks were frequently cut for irrigation, but reported as breached. The *Gazetteer* tells us that 25 breaches took place in 1847, 14 in 1849, 56 in 1850, 45 in 1852 and 28 in 1854. The Government took over the embankments in 1855 and made them watertight. No more wholesale breaches were allowed to take place.

24. When the Government took over the work, it thoroughly strengthened the left embankment behind which the E. I. Railway had strengthened itself, and made a second bank. The Grand Trunk Road which was always breached in old times was much raised and made a third bank, and,

later, the Eden Canal made two more banks, or 5 banks in all, like 5 Satanic chains binding the Damodar and dooming the once healthy and prosperous tract between it and the Hooghly to malaria and comparative poverty. In 1859 the right embankment of the Damodar was removed for 20 miles as the land on the right bank lay at a high level, and in May 1863 the Lieutenant-Governor recorded that the fertility of the area subject to inundation had been greatly improved. Lower down, the Damodar is 20 feet above the level of the country on the left bank; and, further down still, has breached its right bank and divided the Damodar into two streams. While the river freely overflows the right bank in flood time, the left bank of the Damodar is in watertight embankments.

25. Let us now see what happened to Burdwan and Hooghly which were deprived of their overflow irrigation. The *District Gazetteer of Burdwan* (page 41) says—" Dr. French in his special Report on the outbreak of epidemic fever estimated the total mortality at about one-third of the whole population between 1862 and 1872." Lt.-Col. Campbell states of Hooghly :—" It would appear that, before the fever broke out, the Hooghly district must have had

a population of something like 2,000,000 and that during the 20 years the fever lasted, the population fell by 50 per cent." These are the opinions of medical men. And here is the opinion of an engineer. In 1869 Mr. Adley of the Public Works Department says that the belief current among the people is that the closing of the Kana Nuddee has been the cause of all the evil, and that if the Damodar could be let down a remedy would be provided. He himself considered that the closing of the Kana Nuddee had been the fundamental cause of the dire calamity that had devastated those localities. On this point he thought there could not be a second opinion. He was certainly right there.

26. I shall bring down the history of the tract from 1855. The head of the Kana Nuddee had been closed by a bank in 1853, but it breached the bank in 1856 and was left open till 1863, filling three old canals. In 1863 the Kana Nuddee head was finally closed. In 1875 the Jamalpur head regulator was built to again give water to these canals, and connections were made with them; and in 1881 the little Eden Canal was opened. When I saw the tail reaches of the Eden Canal in the spring of 1928 it had silted up

into a watercourse only capable of discharging about one-seventh of its original supply, while the Jamalpur regulator was only run for 2 days in 1927 as the head channel was full of silt and closed as soon as the Damodar rose above a certain height. Bengal irrigation had touched bottom.

27. After my visit to Central and Western Bengal in the winter of 1927-28 I lectured on "The restoration of the ancient irrigation of Bengal" in the British Indian Association Hall on the 6th of March, 1928. This lecture has been published in full, with a map. Of the critics who criticised the lecture at public meetings without allowing the criticisms to be published, I can only say, judging from verbal quotations, that I am glad for the sake of the critics themselves that the criticisms were not published. I answered all published criticisms in the pages of *Indian Engineering* between 30th June, 1928 and 31st August, 1929. To the criticism that I had not been long enough in Bengal to understand all that I saw in company with Government officials, I replied, in Sir Joshua Reynhold's words, that I had spent a lifetime in forming that opinion. And indeed I had.

28. That the "overflow irrigation" of the ancient Bengal rulers is the only one adapted to

Bengal and to all countries similarly conditioned is amply borne out by what has happened in the last seventy years. The Irrigation Department has tried its hand at every kind of project it could imagine except "overflow irrigation." The resulting poverty of soil, congestion of the rivers, and malaria, have stalked the canals and banks, and the country is strewn to-day with the wrecks of useless and harmful works. This has been aggravated by the fact that such works should have been executed by engineers, agriculturists and public health authorities working in accord, and there has been no attempt at working in accord, the accord which Lord Cromer insisted on in Egypt—"Overflow irrigation" with the muddy waters of the river floods is the only kind of irrigation on which engineers, agriculturists, and public health authorities can be in absolute accord, for it enriches the soil, combats malaria and relieves the congestion of the rivers in flood. We may be quite sure that the ancient irrigators of Bengal did not hit upon it at once, but adopted it after trials and experiments lasting over many years. And we may rest assured, after seeing the results of seventy years of abandonment of it, that there is nothing before the country but to return to it.

29. The "overflow irrigation" of Central

and Western Bengal, which at one time poured health and wealth over an area of 7,000,000 to 10,000,000 acres of land is represented in the last published Report of the Bengal Irrigation Department, *viz.*, that of 1927, by an area of under 200,000 acres.

30. I feel myself back in Egypt in 1883, when, under Lord Cromer's guidance, we saved a situation not one whit less desperate than that before us in Bengal to-day. Egyptian irrigation was not only bankrupt in ideas just as Bengal irrigation is to-day, but the Egyptian treasury was bankrupt. Lord Cromer's magic formula saved Egyptian irrigation; it will save Bengal irrigation...." What do the fellaheen want?"..." Do what the fellaheen want, have them behind you, and you will pull through." What pulled Egyptian irrigation through will pull Bengal irrigation through, for when you work with the poor you work with God.

II

The Restoration of the Ancient Irrigation of Bengal, theoretically considered

31. In my first lecture I told you what the "overflow irrigation" of Bengal was, and of its substitute "Zemindari bank irrigation." I also gave you their history. Bengal, with its heavy monsoon rainfall between June and October is marked out for rice cultivation. Such cultivation is possible without flood irrigation from the rivers; but, unaided by flood irrigation, it impoverishes the soil, and can produce malaria though it cannot combat it. The rivers are in flood just when the rice is standing in rain water, and sometimes the floods are high and sometimes low. If the floods are left entirely to themselves, they devastate the country on occasions; and, on occasions, their "overflow" turbid waters bless the country, as they mingle with the rain water in the fields and manure it and help to exterminate the malaria mosquito or to destroy its malignity. If you embank the rivers and prevent their overflowing altogether and leave no openings in the banks, you doom the country to malaria and impoverishment of soil; but that is not all the

harm you do. By confining high floods to their river channels, you congest the rivers to bursting point and expose the country to very serious inundations and devastations.

32. How to enrich the soil and combat malaria, and how to prevent the congestion of the rivers was the problem before the ancient Bengal rulers. In time they solved it and solved it thoroughly, as I have shown in paragraph 18 of my first lecture, where I have quoted Bernier, who was the only man who saw the system actually working and left on record what he saw. After his visit came the terrible times of the Mahratta-Afghan wars on the break-up of the Mogul Empire and the system was disorganized. Read what happened to Egypt and Babylonia when their irrigation was disorganized, and you will see a similar story. Through long years of disorganization the population of Egypt fell from 12,000,000 to 2,000,000; to rise again to 14,000,000. This regeneration of Egypt was easy because Egyptian irrigation was flood irrigation. Babylonia has however a different tale to tell. Its irrigation was perennial irrigation which enriched the country to such an extent that the Arab historians tell us that, when the Arabs conquered the country, the cocks, in crowing, answered each other

in the morning all the way down the Tigris from Bagdad to Basra. But perennially irrigated land, when it has deteriorated, cannot be quickly restored, and Babylonia is to-day, mainly a vast plain over which roam Arab shepherds, with scattered centres of cultivation and crops along the river banks. The groves of 10,000,000 date palms around Basra are no gauge of the 12,000,000 acres of land in the delta.

33. Bengal fortunately has been only irrigated in flood time, and its regeneration will be easy once the right road is taken. The principal difficulty in the way of its regeneration will be the mistakes in the last seventy years; but the regeneration will be easy. We know what to do. We have to do what the ancient Bengalis did.

(1) We have to lead *straight away from the rivers, down the natural transverse slope of the country*, long canals capable of carrying enough river water to mingle with the rain water and enrich it and combat malaria.

(2) We have to space these canals at the right distance apart from each other in order (1) to secure the healthy "over-

flow irrigation " of the whole country; (3) the filling of all the tanks with river water, killing weeds, destroying mosquitoes and providing healthy drinking water, and the feeding of the subsoil water supplies of the country.

(3) We have to make our " overflow canals " or " kanas " broad and shallow, so as to carry the muddy surface waters of the rivers and leave out the sandy bottom waters.

(4) We are to be in a position to take away from the rivers in our canals and cuts enough of river water to prevent the rivers being congested and a source of danger to the country.

The ancients have left us all the works we need, and we have to enter into possession of them and make then once again fit for service. We have a goodly heritage.

34. The main irrigation is done by the rainfall. The monsoon never fails in Bengal. It may end too early but it never fails. And, remember this, if your rice fields have been irrigated by rain water alone, they are weak and cry for irrigation

in October with excessive and costly supplies of poor river water, for river water is poor in October when the monsoon has failed early. If however you have irrigated your rice fields with rain and river water mixed together in the early months of the monsoon when the river water is rich and full of mud, you so strengthen the plants of rice that they resist the hard conditions of an early failure of the monsoon in a way rice irrigated by rain water alone has no knowledge of. River water in the early months of the floods is gold. It enriches the soil and combats malaria and makes you in great part independent of October water. The poor river water of October in a year of early monsoon failure pulls through a limited area of rice, does not enrich the soil and does not combat malaria. It is not only not to be compared with the rich water of the early monsoon, but not with the river water in the October of a year of ordinary monsoon rainfall, when irrigation is not needed.

35. As this seems a good place for giving it, I give you a good instance of the value of early flood water on the Nile. In 1902, the Assiout barrage on the Nile was regulated on for the first time, and the early low flood of that year was forced over 550,000 acres of high-lying land. Immediately

the rents were raised 10 Rupees per acre, as these lands had never seen such muddy water before. They had, hitherto, only been irrigated by late flood water. During 1895, 1896 and 1897 I was Director General of *Land Tax Adjustment* in Egypt when we fixed the land tax of the country for a period of 30 years. I found that in the basins irrigated with flood water, the rents were directly proportional to the quantity of the mud carried by the water as it traversed the basins. This law was like that of the Medes and Persians " which altereth not."

36. The outstanding feature is that the canals are real irrigation canals at their heads, carrying nothing but river water, and, in time, becoming deltaic canals at their heads with the lands on their banks higher than that further away from the canals. These same canals at their tails are drains carrying nothing but water which has flowed through the fields be it rain water or river water which has left its mud in the fields. These drains are in places scoured out channels of considerable magnitude.

37. This outstanding feature is the only key to understand whole sections of the printed government records. It has been the cause of endless disputes and arguments between the Bengal engineers and between them and the Government of India

engineers. An engineer, impressed by the canal in its upper reaches, described it as an ordinary deltaic river; while another, impressed by it in its lower reaches, called it a natural drainage channel. As a matter of fact it was neither. It was a "Kana," an artificially excavated canal, taking its supply from a river through a "Kanwa" or cut made in the river bank.

38. Similar disputes took place over the duty of the water in the canals. "Overflow irrigation," and its successor "Zemindari bank irrigation," have a duty for their river water which is peculiar to themselves. Some engineers trusted to their own observations, some trusted to what it ought to be theoretically, some referred to the Punjab and some to Madras. As I said in para. 6 of the first Lecture :—"They had a supply of river water far in excess of actual requirements, but they needed this excess supply to insure the irrigation of every individual field." The greater the quantity of muddy water you can mix with the rain water, the better the results. The ancients by increasing the supplies of muddy water, steadily improved the lands as time went on, and also decreased the danger of an inundation. The supply for "overflow irrigation" is the minimum for healthy rice irrigation

which is one cubic foot per second for 70 acres. Any extra water above this, as time goes on, is an improvement. A system, which has time as an ally, is a perfect system. Time is the nurse and breeder of all good.

39. It was a pity indeed that none of the old Bengal Engineers were alive in the 19th century when the Government began to interest itself in irrigation. Judging from what happened in Babylonia just before the Arab conquest of the country in the 7th century of our era, there must have been many of them. A great breach occurred on the Tigris which flooded the whole country between the Tigris and the Euphrates, and the Persian King, who then ruled the country, had 400 engineers and subordinates executed. It was owing to the utter disorganization caused by the inundation that the Arabs so easily took Babylonia, but the country suffered more by the loss of all who understood the old methods of irrigation. I often wonder to myself if there is anyone alive to-day who has recollections of having talked with men who had seen the breaches made in the Zemindari banks and then repaired. I do not mean the terrible breaches made by the floods, but the "Kanwas" cut by men. There were 54 breaches made in a single year on the

Damodar, though one or two would have sufficed in a heavily embanked place to turn a dangerous flood into an ordinary one. Between the 3rd and 8th of March I propose to go over the canals in the Hooghly district and would value much any information supplied me on this head.

40. To understand the reason why the mistakes of the last 70 years have made the task of reconstruction more difficult than it was 70 years ago, it is imperative to glance at these mistakes and to draw lessons from them. And as Orissa was then a part of Bengal and the modern works of any magnitude were begun there, I shall include Orissa. The works in Orissa were begun by the "East India Irrigation and Canal Co." which was formed in 1857. The Company made the original plans and the Government engineers passed them.

41. The beds of deltaic rivers, as a rule, have a tendency to rise slowly and so raise the levels of the ground overflowed by their muddy waters. This goes on for many years and then some rivers partially abandon their original main channels and scour out new ways for themselves down secondary channels or convenient depressions. At this stage of their existence, weirs have to be constructed at the heads of the low deepened channels in order to raise

the water surface and allow the rivers to flow in their original channels. The Tanjore, Godaveri and Kistna deltas were in this condition. Sir Arthur Cotton built weirs on the low deepened channels, raised the water surface, and allowed the old rivers to operate again and feed the old Chola canals which were there ready to be fed. He turned concerns which had ceased to be going concerns into going concerns. He did straightforward sound work which was a brilliant success.

42. In Bengal and Orissa the conditions were just the opposite. The Orissa, Midnapore and Damodar rivers were going concerns. The rivers overflowed their banks and were provided every here and there with "Zemindari embankments." Through cuts or "Kanwas" made in these embankments, the country was being irrigated, in a rough and ready way to be sure, but it was being irrigated; and malaria and the congestion of rivers were being combated and the enriching of the soil and the filling of the tanks was in operation. Here the works needed were: —

(1) The clearing out of the ancient "overflow canals" and the strengthening of their

banks or the making of new banks with the excavated material.

(2) Providing the " overflow canals " with regulating heads and sluices, and adding new sluices every year.

(3) Strengthening the river banks, providing paved waterways in the banks for the feeding of the smaller canals; allowing breaches to be made annually at approved places in the banks when the fear of an inundation had passed; and allowing breaches to be made annually as a matter of course, at approved places in the banks where the country was high-lying and there was no danger at any time. As time went on, and the important canals had been provided for with masonry regulators, the secondary and tertiary canals would have been provided with suitable sluices. Such action would by this time have provided the country with perfect overflow irrigation.

43. Instead of this being done, an attempt was made to copy Madras, where rivers which had

not been going concerns were made into going concerns. The only way to do this was to first prevent the Bengal rivers from being going concerns and then make them sham going concerns. And this is what was actually done. The rivers were banked with solid banks in which cuts for irrigation were not allowed to be made. These watertight embankments I have called " Satanic chains," and they are " Satanic chains." The old canals were closed, and the river floods were prevented from irrigating the country with rich muddy water as they had done for centuries through these canals. New canals were dug, some of them running parallel with the rivers and blocking the way of overflow irrigation. Of these new canals, some were called " irrigation canals," some " navigation canals," some " drinking water canals," and there is one under construction called an " October water canal." This perpetual change of name is a counsel of despair. It is like Balak taking Balaam from hill to hill. People were allowed to irrigate from the new canals on condition that they paid for irrigation. Landowners who were protected from inundation and provided with irrigation at the expense of other people, accepted; but the mass of the people, who had been accustomed to infinitely better irrigation free of

charge refused point-blank. The rivers bound by these Satanic chains have become congested and are a menace to everybody; while poverty and malaria are the heritage of the country-side.

44. The Government of Bihar and Orissa appointed an expert committee of engineers in 1928 to report on the floods in the Orissa delta. The Report of this Committee is quoted freely in " *The Statesman* " of the 27th November, 1928, and I quote from " *The Statesman* " :—

(1) " That the embankment system is at the bottom of their troubles, is, the Committee has found, fully realized by the people of Orissa, and one of the most insistent demands made to the Committee by the inhabitants of the semi-protected and un-protected areas is for the complete abolition of the canal system and the throwing open of the fully protected irrigated area to the spill of the rivers."

(2) " The whole system of embankments in these areas seems to have grown up without any reasoned plan underlying it."

(3) "The embankments have come into being solely in the interests of the particular area to be protected with complete disregard of their effects upon other areas."

45. These criticisms apply as well to Bengal as they do to Orissa. But all the Bengal irrigation projects have had one other great enemy to contend against and that is navigation. In irrigated deltas, navigation works well with irrigation on the following conditions :—(1) The canals are first and foremost for irrigation. They are open to boats and steamers, if the widths and depths of water and times of supply of water in the canals are suitable to the boats and steamers. (2) Boats and steamers which cannot accommodate themselves to the depths and widths of the canals or the times of supply of water in them are out of place on irrigation canals.

I give a concrete example. When we went to Egypt in 1883, the country possessed no roads and all transport was by boats on the irrigation canals. Finding that we could not shut a canal or seriously reduce its supply in the interests of irrigation and drainage, we decided to make roads and free the canals of the incubus of navigation. The peasantry

were poor indeed then and the treasury was empty; but Sir Colin Scott Moncrieff put the matter before the landowners big and small and asked them to submit to a cess and let the roads be constructed. To the astonishment of everybody, the landowners responded, and we constructed the roads and freed our canals. To-day, roads and light railways serve the country; and boats and steamers of suitable size use the canals when the canals are running.

46. In deltas like those of the Bengal rivers, where malaria is always an enemy to be counted with, irrigation canals which require to be kept full of water all the year round solely in the interests of navigation and which arrest surface and subsoil flow of water, and which interfere with or have to be reckoned with in all projects for introducing overflow irrigation with the muddy waters of river floods, are a public nuisance in a country provided with roads and railways; when however they are wide and deep and used only for navigation, especially in the vicinity of big cities, they are an unmitigated nuisance. The long coastal navigation canal west of the Hooghly, with all its costly locks and cross drainage works or lack of them, has become a wreck; and nothing in its life became it like the leaving it.

The Commissioner of Orissa of the time prophesied this. He was a practical man.

47. The long coastal canal and waterway, east of the Hooghly, threading its way through the Sunderbans along the whole sea face of the Ganges delta is in difficulties. Its eastern section has always been a costly work, but its western section has recently deteriorated because the run of the tides was interfered with by the Diamond Harbour and other drainage works in which small ineffective sluices took the place of the great open gaps and other substantial breaches formerly made in flood time in the embankments. This eastern navigation line, athwart the whole length of Central Bengal, will be a thorn in the side of the restoration of the ancient irrigation of Bengal. A return to the old state of affairs when the flow of fresh water in and out of so many drainage basins was not interfered with would give the navigation its chance at the western end. As an irrigation Engineer however who sees an unbounded horizon to the future of Irrigation in Bengal and to the claims it will make on the public purse, I throw my lot in entirely with those who calculate that the existing railways, extended if necessary, and the boats and steamers which, without aid and without any expense to the

State, ply on the natural superb waterways of the country, are in a position to meet any present or future demands made for the transport of the stuff carried to-day by special steamers on a special waterway costly to maintain and liable to be infinitely more costly in the future. The days have passed when roads and railways did not exist. Public money is needed, in the interests of the health and well-being of millions of peasants, to provide these roads and railways with openings for the passage of drainage and irrigation water. These openings were forgotten in the past, and have a first claim on the public purse, for they are a necessity.

48. Before leaving the subject I give the opinions expressed by the Indian Irrigation Commission of 1902-03 on the subject of navigation in Bengal.

(1) The Midnapur Canals are saddled with a heavy expenditure for navigation which practically does not exist.

(2) The Damodar river works were originally meant for navigation, but navigation has not come to them.

(3) The Sone Canals have cost £1,500,000 and irrigate 450,000 acres. The Capital cost of these canals includes a sum of

£400,000 for navigation which practically does not exist.

In the selected evidence which accompanied the Report we find :—

(4) The Hon. Mr. D. H. Horn, Chief Engineer, Bengal, said that navigation added 25 per cent. to the cost of the Sone Canals. Navigation has been a failure.

(5) Babu Jamini Mohan Dass, Deputy Collector, Cuttack, said that the irrigation works have rendered a famine in Cuttack impossible. Navigation is not needed by the people.

49. I have so far confined my remarks on the theoretical side of " overflow irrigation " to the Western Bengal irrigation canals, because it is there that all the irrigation projects of the last 70 years have been carried out, and because we have there on a small scale all the questions we are confronted with in Central Bengal on a large scale. In Western Bengal we can easily grasp in a few paragraphs what it would take a volume to describe in Central Bengal.

50. Central Bengal, which we have now entered, is full of the most interesting irrigation and River works to be carried out in the future in any country in the world. When we compare the works to be carried out on the Ganges front with those before us on the sea front we feel the truth of the saying that " it more stirs the blood to rouse a lion than to start a hare." When I first came here I was so struck with every word I heard or saw written about the Ganges, that I determined to see the Ganges after I had spent some days on the Ganges-Brahmaputra river where at one place I was told that I should not be able to see one bank from the other. And I can say with perfect truth, that when I afterwards saw the Ganges at the Hardinge Bridge, I went up to it and stroked its mane. After walking over the river protective works upstream of the bridge, I asked the Engineer in charge why they had provided against Noah's floods, he told me that in the Bell bunds they had provided against a cyclone. The River said " Yes." On this Ganges front, we have the training of the Ganges, and the securing of the head waters of the Hooghly, whether they are principally on the Bhagirathi as they are to-day or on the Jelingi as they were when Rennel made his map. We have the

fixing and maintaining of the head of the Mathabhanga, and its restoration as the great feeder canal of Central Bengal. And then we have the controlling of the head of the Gorai River and its diminution, and the fixing of the works there. These works are all as glorious as they are beneficent, and they need to have put over them the ablest River Engineer in India. It is the only way to do the works economically. Leaving the Ganges to work its will as it has worked it these 70 years, with huge sternwheelers going up and down it, will spell ruin to Central Bengal. I shall return to all these subjects in my next lecture, in which we shall consider the practical side of our problems.

51. In the way of restoration of the old canals there is only one work of any magnitude, comparable in any way with those on the Ganges, and that is the restoration of the great feeder canal of Central Bengal, the Mathabhanga. In ordinary canals which from start to finish carry nothing but river water, work must start from the head downwards; but with the overflow irrigation of Bengal we have other conditions. The irrigation is done principally by rainfall, and the river water is used to manure the rainfall and kill the mosquitoes or deprive them of their malignity. Such canals are real canals at their

heads carrying nothing but river water; while at their tails they are practically drains carrying little but rain water. This leads us to the solution. On such canals we must begin work from the tails upwards, because it is the tails which principally carry the irrigation water. Such work will be rendered easy by the fact that the Mathabhanga in its head reaches traverses the very friable soil of the recent Ganges delta in the north, while in its lower reaches it traverses the compact soil of the old Damodar delta in the south. Once a good opening is made through the compact soil, it will be easy for the Ganges water, with the aid of the current, to scour out a clear passage through the friable soil of the north, just as the Gorai has done recently. Indeed there is more fear of its doing too much than too little. To guard against this I propose two regulators for the Mathabhanga, one near the beginning of the hard clay soil and the other at the head of the Canal on its left bank, which from the first mention of the Mathabhanga over a hundred years ago was always draining away the water of this canal eastwards into the Gorai, while the authorities wanted it go westwards into the Hooghly. By building these two regulators it will be possible to so regulate the supply of the Mathabhanga that

there will be no necessity for a Barrage on the Ganges until Bengal is rich enough to afford such luxuries. Indeed of every work I have proposed for Bengal it can be truly said that it can be started in a small way and be made to prove itself as it goes on. Here, even on this giant Mathabhanga canal, it will be imperative on the Engineers to dig a small canal to begin with, throwing the spoil banks well back. The two masonry works alone will be built to final size. The canal will be annually widened, and each year's experience will be available for the following year.

52. The Barrage on the Ganges will be needed in the time to come, when, as I have said, Bengal will be rich enough to afford such luxuries. I now quote from paragraph 14 of my lecture of the 6th March, 1928. "At this stage the 'overflow' canals will be beginning to show their value and it will be time to control the flood water of the Ganges and insure every year a full flood. This will be done by an Egyptian barrage at a point about 14 miles below the Baral Head. Such a barrage could be built well within deep iron piles in one half of the width of the river protected from the highest floods and built in the dry and the river then turned over it. This barrage will have 180 openings of 25 feet

each, 162 piers of 10 feet and 17 abutment piers of 20 feet each. It will have a length of 6,460 feet between abutments, with a lock. The piers will be 45 feet high and carry a roadway. The regulating apparatus will consist of Stoney gates fitted with vertical hit-and-miss sliding panels so that the current of the Ganges will be broken up into very many vertical fillets, and as the water will issue as through a comb it will fall its 6 or 7 feet at the time of flood with little action on the floor. Over the floor downstream of the barrage a flood of 1,500,000* cubic feet per second will pass with a depth of 40 feet, and velocity of 8 feet per second which is the observed mean velocity of a Ganges flood at that depth. A flood of greater dimensions will be easily accommodated. The heading in flood at the piers will be about 3 inches. It will hold up in flood about 7 feet if necessary. The long weirs and barrages we have built in the past defeat their own ends, and, by forming islands, increase and not decrease the current. The floor will be 150 feet wide and the pitching upstream 100 feet wide and down-

* By an oversight this figure was 2,000,000 in the printed copy of the lecture instead of 1,500,000 (180 × 25 × 40 × 8).

stream 200 feet wide. Such a work will cost £12,000,000 with its training works complete."

53. In Central Bengal the most pressing work is the "overflow irrigation" of the poor sandy districts of Murshidabad, Nadia and northern Faridpur of which I spoke in paragraphs 11 and 12 of my first lecture. "Kans" or "Esparto" as it is known in the western Mediterranean countries, must be prevented from getting possession of these sandy tracts. Muddy river water is one of its chief enemies. In these sandy tracts the old "overflow canals" have been in many places ploughed up and levelled and their traces have been destroyed; but there are still traces of old canals in many places and the best of these might be made a beginning with. In Egypt we have no difficulty about the public domain; and as the permanent settlement of Bengal was made with the owners of lands, there should be no difficulty here about the irrigation canals which must of necessity have been left out. Until the value of the muddy waters of the rivers has been brought home to everybody and all begin to clamour for it, the State might well consider a sluice in a bank, be it small or big, as including the masonry or iron pipe and the channels leading to it and leading away from it.

54. Where these sandy lands are high-lying and abandoned by their owners, and, to-day, the property of the State, or wherever the banks can be protected and made secure on the upper Gorai, say where near the Railway bridge, powerful pumps might be put up and channels led off and experiments made in irrigation with the rich, muddy waters of the early floods followed by the less muddy waters of the ordinary floods. We have to add muddy water to the 50 or 60 inches of rainfall in the monsoon; and in these sandy tracts we may succeed beyond our wildest imaginings. Similar experiments might be made on the Bhagirathi near Berhampur.

55. There is another place, where a beginning might be made, with one or two powerful pumps, to irrigate with the early flood water of the Hooghly, and that is the tract north of Calcutta. A big city like Calcutta would dispose of every kind of superior garden produce in the way Cairo does. In the selected evidence before the Indian Irrigation Commission of 1902-03, we hear Sir Edward Buck, a great authority on Indian agriculture, saying :—" The earlier floods contain all the valuable waters, and these should, as far as possible, be put on the land." I have already given you our Egyptian experience of such water in para-

graph 35. Successful experiments made near Calcutta would be known to the whole of Bengal. Modern pumps are very effective, and lift twice as much water as old pumps and at half the cost. Working for Sir Ernest Cassel in Egypt, we replaced 4 powerful old pumps on the Nile by 4 pumps absolutely up-to-date. We spent £100,000 on the work and added £470,000 to the value of the Estate.

56. If you want muddy water at its best, get it as early as you can from the river by pumps. You can then irrigate by free flow when the flood is established; and, after the flood, you can lift your clear water in winter and secure a winter crop. If there is summer water also available, you can use your pumps and have a third crop. Two crops of vegetables, and a rich crop of leguminous fodders between, are worth much near a big city. If there is only flood water available in the rivers, there are always tanks and wells to fall back upon in winter and summer. Once the flood waters of the rivers are again freely used, all the old tanks, which to-day are more or less discredited, will again take a high place in the economy of your agriculture. The Indian Irrigation Commission and much of the select evidence was strongly in favour of wells and tanks for October irrigation and double cropping.

With so much coal at your doors, wells worked by central electric stations might be found economical.

57. I hear of many who have little confidence in the power of the Government to enter into possession of its old canals. This is where we were in Egypt in 1883 when the country had seen nothing but projects carried out in the teeth of the peasantry. In Egypt, Lord Cromer put an end to such projects. His first question to us officials was: "What do the fellaheen want?" The business of us engineers was to prepare projects which would meet these requirements in a sound manner. He could ignore the hostility of Cairo Pashas and Beys and the powerful French press. He had the country behind him. Under these conditions, in whatever we wanted to do to meet the wishes of the fellaheen, we found the fellaheen landowners, big and small, with us as a body. It was they who suppressed selfish local interests which stood in the way of the common good.

58. We shall have less difficulty here. We have no native aristocracy here, drawn, almost to a man, from Turkey and South Eastern Europe who despised the fellaheen, nor have we a foreign press interested in the failure of the government. We have, on the contrary, the whole community interested in the uplift of the peasantry. But we have

much more than that. We have your enthusiastic co-operative societies working for the health and well-being of the peasantry by the efforts of the peasantry themselves. "Coming events cast their shadows before," and I take it as no ordinary good omen that you have started these societies just in time to undertake this great national work. Strengthen your stakes, lengthen your cords, fill up your ranks, and get ready to meet any tasks which may lie before you. You have difficulties ahead of you, but work with a will and your rivers will never fail you.

III
The Restoration of the Ancient Irrigation of Bengal, practically considered

59. I have been strongly remonstrated with by a well-informed friend for what I said in my second lecture in the latter half of paragraph 47 about the Sunderban route for steamers. He impressed on me the fact that except on the first reach at the western end, which has been thrown out of gear by the Diamond Harbour and other drainage works and accentuated by the substitution of small ineffective sluices in place of the substantial breaches which used to be made in the embankments in flood time, the steamers are not bound to take any particular channel. The Sunderbans have many passages, and the pilots of the steamers select the one they find most suitable for any particular time of the year. He says that very moderate sums spent on these passages under the supervision of an expert engineer of their own would insure a good route at all times of the year. He prophesied that 50 years hence, the steamers would be holding their own in the Sunderbans against their competitors as easily as they have done in the last 50 years. It is his opinion that all that is needed at the western

8

end is skill and perseverance or a return to the old state of affairs when the flow of fresh water in and out of so many drainage basins was not interfered with. This will be returned to in the fourth lecture.

60. The practical point of the greatest importance in the restoration of the ancient irrigation of Bengal is the fact that every work proposed for execution can be started in a small way in a dozen different localities, and each work can be added to year by year until finality is reached. The lessons learnt in one year will be available for the next year, and those learnt in one locality will be available for all other localities. The only exception to this rule is the proposed Ganges Barrage. Of this work I have said that it will be eventually needed as a counsel of perfection, when Bengal has become rich like Egypt and can afford such luxuries. Its cost frightens the timid to-day just as the lecturer on the probable duration of the earth frightened the timid hearer who thought he had said 800 years and not 800,000 years. But even for the Ganges barrage I have thought of a cheap temporary substitute of which I shall speak later.

61. I have spent the last week among the peasantry, and learnt much about the ancient irri-

gation of Bengal from old men who can remember, as boys, the days when the overflow canals were broad streams full of river water, and from younger men who can remember, from hearsay, of how the cuts were made in the zemindari banks. And from what I have learnt I understand exactly what the ancient overflow irrigation of Bengal was and how its natural successor was "zemindari bank irrigation." I have learnt from these men why the peasantry long for the old days when the rice fields and tanks and pools were full of the fish which Bernier said were in abundance. They crave for the fish which were the food of the poor in old days, but which the poor so seldom see to-day. I have learnt moreover from these same men one of the reasons why flood water, and especially early flood water, combats malaria.

61A. I have already said more than once that overflow irrigation combats malaria, enriches the soil and prevents congestion of the rivers which feed the canals. We shall begin with one of the reasons why it combats malaria. The floods in the rivers begin with the same monsoon rainfall which prepares the soil for the sowing or planting of rice. And as the rains advance, the dry and barren plains become damp at first, and then, over extensive sur-

faces, covered with water, and the mosquito larvæ begin to be bred in millions. It is just then that the muddy waters of the rivers come down with millions of eggs of the finest carp at first, later of inferior fish, and finally of shrimps. In the old days of " overflow irrigation " which Bernier saw in the 17th century, the rivers had low banks, while all the canals taking water from the rivers, met the floods open to the floods, *without* any banks across their heads, and the eggs floated down the canals, entering the subsidiary channels and the rice fields full of rain water and the tanks. They soon became young fish. These young fish are real carnivores, and they at once fell on the larvæ of the mosquitoes and lived on them. Guided by the banks of the canals and the watercourses, the eggs went everywhere, and soon all the canals, watercourses, fields and tanks became full of fish and wherever the mosquito larvæ were there were their enemies the fish. This was the " overflow irrigation " of Bengal, which combated malaria, provided an abundant harvest of fish, enriched the soil and made congestion of the rivers impossible. And this is the task before us.

62. When after the Mahratta-Afghan wars the country found itself with uncleaned canals

which could not carry the same supplies as they had done in the past, the peasantry had to raise the banks of the rivers and close the canals at their heads *until the rice was advanced enough to take care of itself*; and then all the banks across the heads of the canals were cut *at the same time*, and the fields of rice were inundated to a moderate depth in ordinary floods with rain and river water mingled together and to a great depth in high floods. At once the fields and tanks were full of young fish and the destruction of the larvæ of mosquitoes began. The peasants wisely said :—" though no one would care to cut the river bank across the head of a single canal, still when they had agreed to cut the river banks at thirty places simultaneously there was no great risk." No villagers could have given such a sound engineering opinion unless they had heard their fathers talk of such things, or had themselves seen the banks being cut. It explains the 40 or 50 breaches made in single years in the Damodar river banks.

62A. With irrigation from running canals and water-courses, all provided with banks of kinds, the fish eggs are distributed over the fields and sheltered and kept alive in the rice fields full of rain and river water. If however, you let the water go helter-

skelter over a large area without canals and water-courses and banks of any kind, as is done on the west of the Damodar, you have a wind-swept lake one day; and, after a long break in the monsoon, a long stretch of dry rice-fields, with every fish dead unless the fish have countless ponds and tanks to take refuge in as they have on the east of the Damodar. This gives an additional reason for the existence of the tens of thousands of tanks and ponds in the once most prosperous parts of Central Bengal.

63. To insure the eggs getting into the canals and tanks at the earliest date possible is one of the tasks of the engineer. The best way to begin under the conditions in which we now find ourselves is to begin utilising what assets we have. Remove the arches from all existing sluices at canal heads, and open the sluices to the sky up to the level of high water in the rivers, and regulate the openings with horizontal timbers so that *surface* water will always enter the canals. Little floating booms directing the eggs into the canals would make the sluices more effective. Where there are no masonry sluices but where there are channels to carry water through the fields under river banks, the banks might be pierced by iron or ferro-concrete sluices of convenient sizes, with moveable mouthpieces attached to them to

catch floating eggs. For the scores of existing little sluices in the banks to be of any use, they would have to be lowered considerably and provided with the same contrivances. Mechanical engineers would see their way to meet all these requirements. With a small expenditure of money and considerable expenditure of brains it would be possible to begin increasing appreciably the fish supply of the peasantry which they so long for and make a determined attack on the mosquitoes everywhere. This attack would gather head every year as the water increased steadily in quantity until we should again see poor fever-stricken villages inhabited by a few anæmic peasants return to their former populous and well-to-do condition with plenty of fish to eat and among healthy surroundings.

64. In the present crippled condition of all the old overflow canals, the fish for stocking the tanks of those who to-day can afford to pay are obtained from fish eggs collected by fishermen at fixed places on the different rivers. The best fish come from the Damodar, while the Ganges fish are considered inferior. The eggs are collected and kept in special vessels and sold all over Central and Western Bengal. The importance of an abundance of fish eggs will become great indeed once a determined

effort is made to again fill the fields and canals and tanks with river water. I am not an expert at fish culture, but it would be well worth while for those who are experts, to see if the closing off of the waters of the Damodar and other rivers by sand banks in summer and the destruction of the best kinds of fish is harmful or not. And whether it is worth while to ensure by pumping the annual examination of the cannibal fish in tanks which will destroy millions of the young carp which we shall be again introducing. Fish ladders at the barrage under construction on the Damodar may have been forgotten. If forgotten they should be added to the work.

65. The question of malaria is so important that I cannot leave it without giving some interesting quotations from newspapers. I shall first give one from a recent Madras paper which quotes a letter from its Tanjore correspondent, dated February 14, 1930. " Dr. Bruce Mayne, Malariologist, now touring in India making a general survey, was here for the past few days. In an interview he said that his study of the irrigation system of this district would confirm the view that Tanjore is an example of the beneficent effect of irrigation in stamping out malaria. He observed that the only cases of

malaria he had come across occurred in dry parts. He left this place for Trichy yesterday."

66. I now give some quotations from the December 21, 1907, number of the *Indian Mirror*. "The East Indian Railway was constructed in 1853-54 and opened in 1855. The line begins in Howrah and runs through the district of Hughli, after the Bally station, almost parallel with and close to the Hughli river. The river bank being higher, the natural drainage was to the fields behind or westward, returning immediately to the river through 'Khals,' natural drains. When the railway line was constructed with an insufficient and inadequate number of waterways for the sake of economy, on the west of the towns and villages on the river bank, the natural drainage of the Province was interfered with and obstructed."

67. "To protect the E. I. railroad from Burdwan onwards, a high embankment was constructed on the east bank of the Damodar to stop the floods. The P. W. D. extended their operations to other rivers like the Rupnarain, Selye, Cossye and other rivers in Midnapore and Orissa. Wherever embankments were thrown up, tanks and artificial lakes were choked with weeds and the crops suffered

from want of fertilising silt. Scarcity and famines have become more frequent and severe, and ague and fever are caused." "The districts of Burdwan and Hughly abound in numerous large artificial lakes and tanks. They were replenished with fresh and pure water by the annual floods of the Damodar and supplied the people with good drinking water. The villages were full of healthy inhabitants and the people enjoyed good health and prospered. All this was changed when the Damodar was embanked to stop the inundations. If our readers would take the trouble to visit the two districts and see the state of the tanks and lakes, they would find them contracted to half their former size, choked with weeds and grass, and the water black and thick and marshy. The villages have a deserted look, and, owing to the heavy mortality, half or more of the houses are crumbling down and abandoned, and the surviving population look like living skeletons."

67. (*a*) "As a medical student, the writer distinctly remembers, the E. B. Railway was opened in 1861, and he can vouch for the fact that there was no malaria in the villages from Calcutta to Chagda. At the end of the rains there would be a few cases of fever but no malaria, as seen in the last 30 years and more. Calcutta folks used to go to

Khurda, Barrackpore, Nawabgunge, Halisahar, etc., for a change of air and benefited by it. The malarious fever broke out in 1861, one year after the construction of the railway in 1860, obstructing the natural drainage of the country eastward on account of inadequate and insufficient waterways in the Railway embankment. The Government had to open charitable dispensaries."

68. We now come to the task of enriching the fields with the fertilising silt of the rivers, feeding the springs of the country and pushing home the attack on the mosquitoes by filling all the fields with water. The provision of *sufficient river water to* mingle with the rain water and enrich it and complete the work of filling fields and tanks with fish is a much more costly undertaking than the beginning of the provision of fish to combat malaria. Unfortunately the Irrigation Department has shut its ears and eyes to the prevention of the wholesale theft of the public domain along the countless overflow canals of Bengal which it calls "blind" and "dead" rivers, though they are the only seeing and living irrigation works in the whole of Bengal. I come from Egypt, where, under Lord Cromer's administration, we turned all the blind and dead waterways of the country into living streams full of vision and

vitality, and I know the value of acting promptly when you have to do anything with the public domain, for possession in time becomes nine points of the law. In my lecture of the 6th March, 1928, I said in paragraph 11 :—" Clean all the old canals and make them workable. Water ran in the past in them and water will run again. Put on 30 engineers on the old canals everywhere to put the boundary pillars on their limits and enter into possession of them and clear out all patent obstructions to begin with." If that had been acted on, the pay of the engineers would have been saved again and again in the valuable land which would not have been lost to the State. But so inured are the engineers of Bengal to failure, that they have lost vision and cannot imagine any irrigation work being such a success that it will be continued generation after generation in one and the same direction, and eventually make Bengal the healthy and wealthy land it once was. They took no action whatever, and the valuable state domain is a prey to any one who cares to appropriate it.

69. The fertilising of the fields with the rich muddy deposit of the river floods, filling the rice fields with fish, and the more concentrated attack on malaria will be done through the overflow canals.

These will have to be made serviceable once more, by having the channels cleared to full width and depth, and banks made with the earth taken out of the beds. This will not however be done at once; a channel 20′ wide at bottom and 3′ deep, say, will first be cleared down the middle of an old canal and the spoil thrown well back to allow of a 50, 60, 80 or 100 feet wide canal being finally made. This canal will be put in communication with the river by a 10 feet wide culvert made in the bank to one side of the future head work. This culvert might even be a cut in the bank protected temporarily from scour in many ways. For it must not be forgotten that all temporary pitching, made of overburnt kilns the bricks in which have been allowed to run together, or made of concrete blocks of 8 sand and 1 cement, will be afterwards available for the final main head work. In sandy ground such as we have in Murshidabad and Nadia and in much ground elsewhere, where the head of water is not serious, if the bed and sides of the cut are overlaid by a substantial jute blanket and covered with pitching, we have a structure which will hold its own against scour. Ordinarily a single line of sheet piling driven down to the shape of the opening and continued back on both sides, with pitching upstream

and downstream of the opening will suffice. It is also a well established fact that obstructions in waterways, made of pitching, fine on the upstream side, of mixed sizes in the middle and coarse on the downstream side, if overlaid by a single foot of masonry turned over the two sides will hold their own against very severe scour. After a couple of years of experiment, it will be easy to establish some form of cheap serviceable temporary works which will hold their own for 50 years if necessary. With sand, coal, cement and iron we have an asset the old world engineers had no knowledge of, and it is for this reason that the only modern irrigation word in Bhagalpore is " sulus " or sluice. Knowing the word and what it means let us proceed to make practical use of it—Bengal might show the world the way to do this, for its needs of such devices surpass those of any country in the world.

70. In digging down the centre lines of old canals such as we have between the Hooghly and the Damodar, let no mistakes be made of leaving the dirty, grubby, malaria infected crooked channels and taking short cuts, as I have seen in one place. No malaria can be combated on these terms. Let the cleaned channels go down the middle lines of the once magnificent waterways and let them be put

in communication with every filthy pool and tank on either side which are there to-day, and give the poor people a chance of escaping malaria and having good fish to eat. They all look as if they needed both. Such mistakes could never be made if the Public Health, Irrigation and Agricultural officials had to work in accord with each other.

71. We shall soon be speaking of Representative Boards but I may say here that if at any stage of the river, especially when danger has passed, the Boards are prepared to act, they should on their own initiative cut the banks at the heads of canals and at other suitable places, as was done by the leaders of the people in the old zemindari bank irrigation days. This would indeed put heart into the peasantry who to-day are depressed to the very ground.

72. Once these old canals are running again, we shall find that the boatmen will cover them with their little boats as of old and supply for some months cheap and easy communications. The boats will be made to suit the canals and not the canals the boats. The want of navigation of this kind or of any kind is keenly felt by the villagers west of the Damodar, whose lands are to-day a huge lake from

end to end. These tracts will have such communication when the future canals with banks will be made from north to south.

73. No bank of a river should ever be removed continuously along a considerable length as has been done on the right bank of the Damodar. The bank should be breached in the places where it is good for future canals to be, and the beginnings of these canals should be dug as has been shown in paragraph 66, and the canals increased in size year after year. All other places would be left alone and have breaches made in them only on the special occasions when they were needed. In this way banks would be gradually formed which would eventually rise above the level of the water, for the newly formed mounds of freshly thrown up earth would be covered with scrub, brushwood and young trees which would screen the water of its coarser particles and deposit them on the mounds on which they were growing. If you remove the banks of rivers altogether, great part of the water goes down hollows and depressions where you do not want it to go, and it does not go on the high-lying lands where it ought to go. But this is only the beginning of troubles. By having miles of bank removed to the same level, you make the top film of water of the river which

has little coarse sand in it flow out of the river in such enormous quantities that the river cannot possibly carry on all the coarse silt and it drops it on its bed and gradually raises the bed and produces a state of affairs which one cannot contemplate without great anxiety.

74. Such wholesale removal of the top film of water on miles and miles of length is very different to the removal of the upper water of a river by canals. The canals, say, are 200 feet in width and 6 feet deep. They are 5 miles apart. The bank on the whole of the 5 miles between the two canals is intact and prevents the surface film of water from escaping; while the canal takes water away down to a depth of 6 feet and not only the top film. Such removal of water charged with lighter deposit than the mean deposit of the river has an infinitely smaller effect on the river than the other. The experience gained on hundreds of canals the world over has taught engineers that the effect is negligible. You have the right kind of water in your canal and the river adjusts itself to the slight change by changing its method of disturbing its bed and by modifying the shape of its section. Such action it cannot take when the change is too great. It is like pulling

a rope; up to a certain point it can change its section, beyond that it will be broken.

75. In my lecture on the 6th February, 1928, I said in paragraphs 28 and 29—" In Western Bengal I propose acting on Shakespeare's advice that ' there is some soul of goodness in things evil, would men observingly distill it out.' The Damodar banks are veritable Satanic chains, but as ' what cannot be eschewed must be embraced,' we shall make use of them. The different canals which originally led off from the left bank of the Damodar towards the Hooghly are called rivers. They are canals. These must first be restored and have all obstructions removed and be cleared and provided with light banks made of earth taken out of the canals. Never again shall there be the *water-tight-compartments* called banks. The initial putting into working order will be the work of the State. The working of the canals will be left to the district boards. At suitable places east of Burdwan, 10 feet wide cheap regulators will be built by the State and connected by canals with the existing canals or along traces of them. They will cut across banks and roads and through the E. I. Railway openings." These statements of mine are thus criticised by the Hon'ble Member in charge of Irrigation at the

Legislative Council Meeting of the 11th August, 1928 :—

" It could not now be seriously suggested that they should cut down the Damodar left embankment and let loose the flood on an unprepared tract of country." " Sir William talked of the claims to flood and ' October water ' of the people on the left bank of the Damodar from near Burdwan southwards. The last thing they wanted was to be exposed to the Damodar floods."

This is not a criticism, it is a travesty. I certainly said that the people on the left bank of the Damodar should be given flood water, but I never said that they should have it in one gulp. And the extraordinary thing about it all is, that the cutting down of the banks is the very treatment the Orissa Commission of 1928 recommended for considerable lengths of bank in Orissa; and the people there are protesting against it very strongly.

76. We now come to the training of the Ganges, which is an absolutely essential work, if we are ever to have our Mathabhanga Canal supply for Central Bengal. A canal which may be discharging 200,000 cubic feet per second in one year and 500 in another cannot be irrigated from. We say in Egypt, " does a fish begin to go bad at its

head or its tail?'' The Mathabhanga has gone bad at its head. When I saw its head in February, 1928, the river was in an ideal position for fixing, with very hard clay on the left bank and good clay on the right bank and a clean and beautiful channel for the Mathabhanga canal which had just discharged 187,000 cubic feet per second in the flood. I saw it when it was dry and paced its bed and noticed its depth in flood, and regretted that an effort was not made to fix such a favourable state of affairs for ever. The protective works needed would have been easy to execute and economical as there was good clay on both banks. Once the Ganges was fixed at the Mathabanga head, a beginning could at once be made with the canals in Jessore and Khulna districts.

77. On the subject of river training and protective works on the Ganges I had proposed the following amplification of what I had said in my lecture, in the June 30, 1928 number of *Indian Engineering*.

" Training and protective works on the Ganges, with its long and broad sweeps will be anything but costly. The Hardinge bridge protective works were designed against a cyclone. Speaking of the river generally, away from towns and bridges, I consider all stone strewn along banks as thrown away

unless it is thoroughly renewed after each flood for five or six years at the least. And then it is not very effective. What is wanted is a series of massive immovable single spurs of stone *of every size of rock, big and small mixed together.* They should be put up at well chosen sites, and cost between £4,000 and £8,000 a piece, or £6,000 on an average. All to be stone below winter water level; and, in great part, brick kilns over-burnt *in situ,* above winter water level. There are places on the Ganges where a single spur of this kind will keep the current away from the bank for 3 or 4 miles. A few very big spurs will be more economical than many cheap ones. Pitching slopes is absolute waste of money (except in front of towns where such work must be done, however expensive it may need to be in order to be permanent. Towns can afford luxuries which fields cannot). Massive single spurs, well tied back, at an angle of 45° to the current and thoroughly renewed for 3 or 4 years will be a permanent landmark on the river. For training works no trees surpass acacias, and there is no lack of them on the Ganges."

78. At the Legislative Council meeting of the 11th August, 1928, the Hon'ble Member in charge of Irrigation criticised my proposals, and I replied

in the September 22nd, 1928 number of *Indian Engineering.*

"The Minister calls the training of the Ganges as 'one of the most complicated problems of river training in the world.' The whole length of the Ganges in Bengal is 200 miles. It is scarcely ever above the level of the country, and then only just over, with ordinary banks here and there. The Mississippi is for 1,000 miles well above the level of the country with massive embankments. The Ganges traverses an old established country with fixed floods, while the Mississippi traverses a new country under settlement with its floods ever on the increase. (The well trained and protected banks of the Mississippi prevent the bed of the river from becoming wider, and so the water surface is ever rising higher and higher. The problem on the Mississippi is the opposite of that on the Ganges. The Ganges could be trained and protected like the Mississippi without any fear of the water surface rising.) *You run no risks on the Ganges and can be as bold as you like.* The Minister says that the Ganges scours in places 120 feet. No one would put in a spur where

The additions within brackets here and in para. 77 are for the sake of non-professionals.

the river was 120 feet deep. He would put it some way upstream, and the deep hole would be silted up by the river itself; while as the spur settled gradually in the bed of the river, it would be added to at the top by 'sausages' of mammoth bricks or stone until it took its final position and there it would stay till the day of doom. I said that a few kilns of bricks burnt solid at the site of each spur with stone, costing from £4,000 to £8,000 per spur, would suffice, and I think it would. The Department has never made a single experiment these 60 years, and is in no position to criticise me." What I propose for the training and protective works needed on the Ganges will be given in my fourth lecture.

79. In paragraph 52 of my second lecture I spoke of the proposed Ganges Barrage. For this barrage I recommended a length of 6,460 feet with a waterway area of 180 by 25 by 40 for a discharge of 1,500,000 c. feet per second. This is, I calculate, the normal maximum discharge with a normal maximum velocity of 8 feet per second. If the Ganges comes in spate and the Brahmaputra happens to be low, there may be a discharge taken, giving abnormal results; but such discharges do not affect the needed width of the work. They accommodate themselves by having a velocity of approach above

the average. I allowed a play of 5 feet and made the piers 45 feet high. If one is nervous, let him give a play of 10 feet and make the piers 50 feet high, but let him not touch the width. This extra height adds practically nothing to the cost. The width is ample. The old long barrages defeated their own ends.

80. As the maintaining of a good supply of river water in winter and summer would mean so much to the Hooghly and would permit of very valuable crops on its banks, especially near Calcutta; and as the expensive barrage will not be needed for years yet, I propose the construction of an Indian weir or anicut on the Ganges. This work could be constructed at any point determined upon as the final head of the Hooghly on the Ganges, and so trained and protected that the river would be fixed there for ever. Indeed once the Hooghly head has been fixed at some point on the Ganges, and the Ganges trained and protected, it would be possible to put up a row of big pumps and lift Ganges water into the Hooghly as Nile water was lifted in Behera till 1895. It might be found, and I think it would be found, that water pumped up some seven feet in sufficient quantities was cheaper than that raised by a weir, de-

bited with interest charges and maintenance. It would certainly be much more elastic and preferable in many ways. I am sure that pumps have a great future before them in Bengal. Mr. Finlow, Director of Agriculture, has just written and told me that he is pleased indeed with the little experience he has had of pumping.

81. As I have just spent six days on the Damodar river and its canals and among the peasantry who are the principal victims of the mistakes of the last seventy years, I cannot keep silent about the wrong inflicted on the 250 villages and hamlets swamped annually with flood water on the right bank of the Damodar, on the inhabitants of 800,000 acres of land on the left bank of the Damodar deprived annually of their rights to Damodar water which they had enjoyed for hundreds and may be thousands of years, and about the very critical condition of the River Damodar itself. All these have the very first claims to the public purse if there is any money available for irrigation and river work. And yet, when money is available, they are all left to themselves, and the money is spent on lands which have been in no way injured or hurt and which are outside the delta of the Damodar altogether and which have no claims whatever on the water of the

Damodar river. Not only is this so, but the very water which is being given to these privileged lands is the water to the whole of which these afflicted lands have an absolute claim.

82. Knowing as I do, from my experience in Egypt, of the great responsibility one shoulders when one sets himself to repair past errors, especially errors as colossal as those on the Damodar, I can only attribute the gross injustice of the Damodar Canal and weir under construction, to the extraordinary timidity which the Irrigation Department has shown these 40 years in undoing the evil done on the Damodar, an evil every engineer longs to see removed. The men who are going to undo the evil, will take their reputations in their hands, and may God be with them when they enter upon their tasks.

83. We now come to the question of the maintenance of the canals once they begin to operate and to really irrigate the country. All irrigation canals, and especially those which carry flood water, need to have their beds cleaned annually and their banks repaired with the stuff removed from their beds. The old canals which are to-day called " dead rivers " or considered " blind rivers " were once living streams of rich flood water. When they were neg-

lected and their clearance not insisted upon by the ignorance of the authorities, they became blind and dead. The servitude of building up the banks with the silt taken out of the rivers was known as " pulbandi " in the old days when the canals met the floods all open to the flood, and the river banks were small unpretentious works. When the canals began to be neglected and became unequal to the task of meeting the floods with their heads open, they had to be closed with earthen banks as we have explained in paragraphs 61 and 62, and the river banks became important public works. The term " pulbandi " was now applied to repairing the banks and closing the breaches. The service known as " pulbandi " in Bengal was known as " sukhra " or " corvie " in Egypt. It was obligatory on all the village population, as doubtless it was in Bengal. It was in existence in Egypt when we went there in 1883, but beginning with 1885 we allowed the village population to redeem itself by paying a cess, and by 1889 the corvie for canal and drain clearance and bank repairs was abolished in Egypt. After having seen both personal service or a cess, I can say, without any hesitation, that a cess is a hundred times as fair as personal service, and much more effective and more economical.

84. When the time comes here, the engineers will, as soon as the flood is over, measure up the work to be done and estimate its cost. The Representative Boards will then meet, discuss each item of the bill and have the power to change or modify. The members will finally sign the document which contains all the items passed by them, and the engineers will be responsible that the work is done as approved. The cess will then be fixed. It will be a "pulbandi" cess which cannot be diverted to any other object, not even to education.

85. When the flood comes in Egypt, the whole village population is under obligation to guard the banks and be ready to cut banks or repair them. Every village or hamlet, according to its size, is under obligation to send a fixed number of men to guard the banks. The village headmen turn up with their contingents and take charge of the banks and are responsible for them, working under the orders of the engineers and civil officials. They cannot leave the banks without written permission from the engineers. Here in Bengal, if the people desire it, Representative Boards will fix the times when breaches, protected as explained in paragraph 69, may be made in the banks as was done in Zemindari

bank days; and flood water will be let into the canals until such time as the canals are dug to full size and the regulators built likewise to full size. This responsible work will be difficult at first because the experience gained in the past has been lost; but it is wonderful how soon experience is gained if there is good will and determination to succeed. Your responsibility will not be greater than ours was in Egypt when we sent home the hundreds of thousands of the corvie who had done the canal clearances for 6,000 years, and we took on ourselves the responsibility of doing the work by contract. The whole cotton crop of Egypt was at stake, and everybody predicted failure. I remember well how in July, 1885, I was in such a state of nervousness I could not sign my name on my pay sheet. It was the same when I shut the old condemned barrage on the Nile, and all the old pessimists came down in steamers from Cairo to see it topple over, and my chief, Sir Colin Scott Moncrieff also came down and patted me on the back and said that if we succeeded, I'd get the credit for it, while if we failed, he would take all the blame. You Bengalis are a clever people and will soon learn, and you will have the help of the well organized Meteorological Department. Your power of co-operating will stand you also in good stead.

86. The annual measurement of irrigated fields and payment for individual irrigation is the mildew which blasts irrigation in Bengal to-day. It blasted it in the early days of the modern irrigation canals when officials went about every year in the rice fields deciding which field received only flood water, which half flood and half rain, and which received only rain water! When I worked for eleven years as an irrigation officer in the United Provinces, I used to find it heartbreaking to see all the poorer agriculturists putting off and putting off the evil day (to them) of irrigation until frosts had injured their winter crops, or the time of sowing had almost passed for their monsoon crops on the occasions when the rain came late and scanty. When I came to Egypt the very first thing that struck me was the way in which the fellaheen looked upon water as their best friend, they took it on the first day they wanted it, and secured *bumper harvests in every year*, a thing I never saw on irrigated land in the United Provinces.

87. In the perennially irrigated tracts of Egypt, which are like the Punjab, as well as in the flood-irrigated parts, which are like Bengal, the land is taxed in blocks, and the land and irrigation taxes

are clubbed together. The land tax and the irrigation tax is applied to the whole area of each block of land. All the blocks suffer together individually from oversaturation, or benefit together from suitable irrigation and suitable rise of spring level, allowing easy well irrigation. One single tax is as fair in an irrigated arid region as a single tax is fair in a region blessed with plentiful rainfall. The first two paragraphs of page 800 of the 3rd edition of "Egyptian Irrigation" give a resumé of the land tax system of Egypt which works so well. It allows every land-owner to look on land and irrigation as one, and encourages him to irrigate his fields when they need water; it does not encourage him to put off irrigation to the last moment and often lose no small part of his harvest. It also insures quietness and happiness at home instead of uncertainty and disquietude. This mental factor is worth considering in the taxation of irrigated lands. Irrigation means insurance against drought and the vagaries of rainfall, and a fixed combined land and irrigation tax, to be paid year in and year out, insures against the worries of watching winds and clouds and seeing if one cannot evade part of the tax; while all the time, crops are losing value. It protects a man against himself.

I have so far spoken only of the *agricultural* and engineering side of the question, but when we consider the side of *public health*, we can see that a fixed cess or a combined land and irrigation tax is the only form of taxation which will touch the question of public health. To get rid of malaria you must encourage to the utmost the irrigation of whole blocks of land. Scattered field irrigation will be of no use whatever. See paragraph 6 of my first lecture.

88. Now what do we see to-day on the Government canals, or drains, or many miles in length of any old canal they touch, even if they only pour a dribble into it for a couple of days per annum? We see the peasantry doing their best in all ordinary years to avoid the canal water and the water which is called canal water but which is not. We see them plagued with malaria and without any fish to strengthen them. We see them in the middle of dull surroundings, with nothing to take them out of themselves. Introduce the wholesale overflow irrigation which they had until 70 years ago, and you will have a physical, mental and spiritual resurrection. You will have the co-operation of all for the benefit of all, and this will at once add interest to their lives. They will wake up and find life interesting. They will find their old enemy malaria

loosening its hold on them. They will have abundance of fish to eat, and they will see prosperous days before them and before their neighbours. In this prosperity and well being the Government will have its full share; and may God's blessing be with all those who help to bring this about.

IV

The Restoration of the Ancient Irrigation of Bengal in our Day

89. I have established in my third lecture that the ancient irrigation of Bengal combated malaria, provided an abundant harvest of fish, enriched the soil, and made congestion of the rivers impossible. The lands were irrigated by long canals led straight away from the rivers; and the water was delivered during the floods into the fields by watercourses between the fields. Ordinarily the abundant monsoon rainfall sufficed for the maturing of the rice crop, and the river water mingled with it and manured it; but to provide for breaks of rain in the monsoon, and ensure the rice fields being always full of water in order to keep alive the valuable fish, which, in the absence of tanks, had nowhere to flee to, the amount of flood water needed for irrigation was the same as that needed for rice when there is no rainfall, and that is, as a minimum, 1 cubic foot per second for 70 acres. Where drainage is good the cultivators use 1 cubic foot per second for 40 acres. Mr.

Buckley, in his book on Irrigation in India says: "The cultivators in Behar and Orissa, during the rainy season, when the rice crop is under irrigation will often endeavour to drain the water off their fields and irrigate them again from the canals whenever a freshet in the river brings an extra quantity of silt into the water." All wire-drawing of supplies is very harmful to effective fish culture and agriculture, so I learnt from the peasantry.

90. The importance of a high spring level in Bengal and consequently of plentiful irrigation in order to combat malaria effectively is insisted upon by Dr. Bentley. This view is sound for this reason among others: a high spring level insures rice fields full of fish against drying up and so insures fish against destruction when they have no tanks to flee to. Mr. N. Bose, the agricultural officer of Hooghly says that the difficulty in Bengal, as a rule, is to keep moisture in the land. I have often noticed that the winter and summer pastures in damp fields of rice stubble are miles better than they are in dry fields. Hear what Cheng-ki-tong the Chinese General said at the Paris Congress in 1889:

> "I may add that without these gigantic irrigation works, the Chinese could never

have carried to such a pitch of perfection one of their most important industries. I speak of pisciculture. Thanks to the abundance of water my countrymen have devoted themselves to the breeding of fish. The spawn is everywhere carefully collected and sheltered in some spot where a perennial supply of water can be assured. The irrigation reservoirs teem with fish. During winter, the rice fields are fallow; the water is led into them, and they are instantly full of carp. This industry allows us to make fish a considerable factor in the food of our people."

One understands from this why there were abundant fish in Central Bengal in Bernier's day. One also understands the great value of perennially swamped areas and " bhils " full of water. The drying up of these, and the destruction of the fish in them, increases malaria. Rice lands alternately under water and dry, in which fish and shrimps are killed off are the allies of the mosquito. In this connection it is worth while referring to the recent words of Dr. Bruce Mayne, the malariolo-

gist, quoted in para. 65 of my third lecture :—" His study of the irrigation system of Tanjore confirmed the view that Tanjore is an example of the beneficial effect of irrigation in stamping out malaria. The only cases of malaria he saw occurred in dry parts." Of course Tanjore uses all the water in flood it can use.

91. The Report of the expert committee on the embankments and irrigation on the Orissa rivers, already quoted in para. 44 of my second lecture, has one significant sentence :—" To continue as at present is merely to pile up a debt which will have to be paid, in distress and calamity, eventually." Every word of this sentence has been true of every River and Irrigation project in Central and Western Bengal these 70 years. Every year of delay in re-introducing the irrigation of the past is encouraging people to appropriate more and more of the public domain. Every year is increasing the difficulties on the Damodar and kindred rivers. Every extra year of the plague of malaria and of the deprivation of fish, the one strengthening food of the peasantry, is adding to the debilitation of the peasants themselves. And every year of delay is sapping the mental fibre of the officials, and, in spite of patent proofs to the contrary, encouraging them to accept

as an oracle, the old official counsel of despair thus recorded :—

> "In this tract we have a number of dead streams which were once large rivers... The rivers above alluded to are already dead; to resuscitate them is practically impossible......It has been urged that the Government has been apathetic.... We do not concur, but consider that money spent would simply have been thrown away......These rivers can never be reconverted into live streams by the action of man."

92. This Jeremiad was written many years ago of the old canals on the east of the Hooghly, which Bernier twice saw working about the middle of the 17th century, and which he so much admired. The great feeder of this system, the giant Mathabhanga canal, owing to a slight shift of the channel of the Ganges left entirely to itself, was actually discharging in the flood of 1927 a discharge of 187,000 cubic feet per second. The flood of 1927 was a quite ordinary one. In the spring of 1928, when it was dry, I measured the section, and it was a

wonderful section capable of carrying a wonderful discharge. Half this body of water would have sufficed for the irrigation of 6,000,000 acres of rice, or the whole of Jessore, Khulna, and the eastern sections of Nadia and the 24-Parganas, and much more besides if land had been there to be irrigated. This stream, forsooth, is still called a " dead river," " to resuscitate which is practically impossible," etc., etc. I have received from Rao Bahadur Nilakanta Ayyar, Superintending Engineer of the Tanjore delta, the copy of an informing lecture just delivered by him on the Tanjore Works. The Tanjore canals utilise about 35,000 cubic feet per second, which is $\frac{1}{5}$ of the measured discharge of the Mathabhanga, and yet the Mathabhanga is called a " dead river." There must be something specially depressing in work continued for 70 years on wrong lines, which forces the Engineers still to call the Mathabhanga and all the canals dependent on it " dead rivers," and so excuse themselves from doing anything to the head of the Mathabhanga on the Ganges, though prompt action taken in 1927-28 might have secured this inestimable asset to Bengal for ever. It is not yet too late.

93. The only thing which could get the Irrigation Department out of its groove would be an

intra-departmental enquiry of engineers, doctors and agriculturists, working together under the presidency of a Civilian. Here the President would be a real master in his own house, and the whole position would be one of life and vitality. Bengal never sees such Commissions on its canals and rivers. In Committees of engineers presided over by Civilians, the really able Presidents are not masters in their own houses. Technical questions on rivers, asked and answered, meaning nothing in Bengal though they would mean much in virgin forests and plains, can completely confuse issues. Irrigation and river banks in flood time, under the special conditions which prevail in Bengal, concern :—

(1) The combating of malaria.
(2) The harvest of fish and rice.
(3) The congestion of the rivers.

It is the ignoring of public health officials and agriculturists in the matter of irrigation and river banks which has landed Bengal in the morass in which she is to-day.

94. The problems east of the Hooghly may or may not be difficult, but the man has yet to be born

who can say that the problems east of the Damodar are difficult. They are easy but they need *courage* and alertness in execution. The tract between the Damdoar east of Burdwan and the Hooghly was irrigated until 70 years ago, by the wrecks of the seven canals seen to-day on the ground. Six of them were main canals and one a tributary of one of the canals. *Beginning at the* south end I give in the following table,

in column (1) the names of the canals;

,, (2) the net areas commanded approximately in acres;

,, (3) the discharges required in flood in cubic feet per second;

,, (4) the width required at the *heads* in feet;

,, (5) the widths at the tails in feet;

,, (6) the provisional depths of water in feet. The water is to be in the calculations 1 foot above ground and 4 feet in soil.

TABLE A.

Names.	Areas.	Discha	Widths. Head.	Widths. Tail.	Depth of water.
(1)	(2) Acres.	(3) C. Ft.	(4) Ft.	(5) Ft.	(6) Ft.
(1) Kana Damodar ...	125,000	1,800	120	30	5
(2) Kana Nuddee ...	210,000	3,000	200	100	5
(3) Gya ...	35,000	500	40	30	5
(4) Ilsura ...	130,000	1,900	130	30	5
(5) Gargur ...	110,000	1,600	110	30	5
(6) Banka ...	105,000	1,500	100	30	5
TOTAL ...	715,000	10,300	...	...	...

The gross area is 820,000 acres.

95. Before I go straight on with these calculations and with all the other calculations before us, I must finish the history of the Damodar, which I can now do in an intelligible manner with the aid of the table I have just given. I begin with the Kana Nuddee and the Damodar, as they were the last of the old canals to be shut off. The Kana Nuddee was closed by an embankment in 1853, but in 1856 a breach 350 feet wide took place in the embankment, and, through this, the floods of the

Damodar found an escape. This breach was left open, year in and year out, for 7 years till the end of 1862. In 1863 a metalled road was made from Mymari to Chakdiggee, and, apparently, to save the expense of a bridge, the opening of 350 feet was closed by an embankment and the metalled road taken over it! The Kana Damodar used to take off from the right bank of the Kana Nuddee; and so, in a moment of time, 360,000 acres of land densely packed with inhabitants in the best section of what had been the richest agricultural tract in the whole of India (see para. 20 of the first lecture) was deprived of its irrigation. So say the engineers. The peasants say that they were at the same moment deprived of their fish supply. The health officers, in their history of this tract, say that a plague of malaria broke out there in 1864, or the year after the breach. All 7 canals have now been shut for close on 70 years, with malaria everywhere and fish nowhere, on 800,000 acres of land.

96. The peasantry cried for relief. Relief (if such it can be called) was given by the construction of the Jamalpoor Regulator in 1875 and the Eden Canal in 1881. The Jamalpoor Regulator opens on to the Kana Damodar and the Kana Nuddee by a canal with a bed width of some 15 feet and depth of

some 3 feet. Its height of bed prevents it from taking low water, and official regulations prevent it from taking high water. It ran for 2 days in 1927 and 8 days in 1929. The Eden Canal feeds the Gya with a sluice which opens on to rice fields; and it feeds the Gargur, the Ilsura, the Kana Nuddee and the Kana Damodar with little watercourses called canals, on an average some 8 feet wide and 3 feet deep. They are only opened when the peasants have promised to take the water and *pay for it.* If no promises are forthcoming the canals are promptly shut. These trumpery canals, a few feet wide, kept under lock and key and often closed, and which are credited with 10,000 acres of irrigation in 1929, are called the feeders of the six ancient canals which formerly irrigated 700,000 acres free of charge, supplying the peasantry with abundance of fish and protecting them from malaria.

97. I have just said that the Eden and Jamalpoor canals were credited with the irrigation of 10,000 acres. I shall explain this expression. The fact that these canals (may be, for only a few days per annum) let a little water dribble into the ancient canals, has put these ancient canals into the category of "protected rivers," and subjected the peasantry to pay for lifting or taking water out

of them on lengths of 10 and 12 miles each. The water so lifted or taken is generally rain water which has drained out of the fields. Scott may have been hit 4 times under the belt. These peasants have been hit 50 times under the belt during the last 50 years. Such is irrigation in Bengal today. It is unique in India. It is unique in the world, and thank God it is so.

98. Let us now contemplate the table in para. 94. In making preliminary estimates of the cost of these works we have the height of the Damodar flood as an asset. It allows us to make great economies in the number of openings required for the regulating heads. We have another asset in the winding channels of the old canals threading their way through soil, compacted by muddy water flowing through it for many hundreds, may be thousands, of years and by roots of grass and shrubs. It will allow of a velocity of 3 feet per second. As the canals widen themselves in the lower reaches, let more and more water be sent down from the Damodar. The greater the quantity of water, the more damp the country, the more numerous and healthy the fish, the less the malaria, the greater the enriching of the soil, and the less the congestion of

the Damodar. What a wonderful combination. Let the head regulator be taken up boldly to a point near the Damodar. The existing timidly retired Jamalpoor Regulator, with its piled up banks of sand, is a warning for all time. Regulators will be needed in the first reaches of the canals where the public domain has been a prey to the landowners. Very great care must be taken that the sites of the head regulators are kept away from the sites of the heads of the ancient canals. I have seen bad accidents due to such mistakes.

99. Allowing for the valuable windings of the old canals, which must be scrupulously respected, I have made Table B. In which

column (1) gives the names of the canals;

,, (2) gives the length of the canals in miles of 5,000 feet;

,, (3) gives the mean area of excavation in square feet;

,, (4) gives the number of millions of cubic feet of excavation.

TABLE B.

Name of Canal. (1)		Length. (2) Miles.	Section. (3) Sq. Ft.	Earthwork (4) Mil. C. Ft.
Kana Damodar	...	60	320	96
Kana Nuddee	...	40	620	124
Gya	...	30	160	24
Ilsura	...	50	340	85
Gargur	...	50	300	75
Banka	...	50	280	70
Sarasuttee	...	60	200	60
TOTAL	...	340		534

Estimated Earthwork 534,000,000 c. feet
@ Rs. 8 per 1,000 = Rs. 43,00,000
Contingencies @ 33 per cent. = ,, 15,00,000

TOTAL ... Rs. 58,00,000

This means Rs. 8 per acre on 715,000 acres. This is an absolutely outside figure. There is so much open channel available everywhere that the money saved will easily pay for every contingency including the land which has in places been stolen and the silt clearances of the canals for the first three years. Any man who steals the compact soil of the banks, robs his neighbour and robs the whole community. The co-operative societies should devote themselves to the preservation of these valuable assets of the country and encourage the growth of a healthy public opinion on this point until the Government takes action.

100. I now give Table C which lets us know the cost of the necessary masonry works. In this table

column (1) gives the names of the canals;
,, (2) gives the canal discharge in cubic feet per second;
,, (3) gives the cost of the Head Regulator in Rupees;
,, (4) gives the cost of the ordinary Regulators in Rupees;
,, (5) gives the total cost.

TABLE C.

Name of Canal.	Discharge.	Head Regulator.	Regulator.	Total.
(1)	(2)	(3)	(4)	(5)
	C. Ft.	Rs.	Rs.	Rs.
Kana Damodar	1,800	85,000	45,000	130,000
Kana Nuddee	3,000	120,000	70,000	190,000
Gya	500	35,000	15,000	50,000
Ilsura	1,900	90,000	50,000	140,000
Gargur	1,600	75,000	40,000	115,000
Banka	1,500	75,000	40,000	115,000
Sarasuttee				
TOTAL	...	480,000	260,000	740,000

Cost of masonry works	... Rs.	7,40,000
Contingencies @ 33 per cent.	,,	2,60,000
TOTAL	... Rs.	10,00,000

Earthwork	... Rs.	58,00,000
Masonry	... ,,	10,00,000
TOTAL	... Rs.	68,00,000

or Rs. 9½ per acre over 715,000 acres, which will be once again the richest agricultural land in India.

101. As I have proposed the entry of large quantities of river water to mingle with the rain water in the old Bengal manner, we must make provision for it, though river water is not rain water. Plants well irrigated with river water stand temporary difficulties which overthrow weak plants; and a depression full of carp is not a depression without a carp in it; but we shall make provision. The drainage of the tract is disposed of by the Kantool Nuddee Escape into a practically tideless reach of the Hooghly and by the Sijhberia Masonry Escape into a tidal reach. The Kantool is 30 miles long of 5,000 feet each and is a fine carrying channel. We shall add 800 square feet to its section by means of 120,000,000 cubic feet of excavation.

	Rs.
Excavation 120,000,000 at Rs. 8 per 1,000	=9,60,000
Contingencies ⅓	3,20,000
	12,80,000
We shall also have 4 additional Sijhberia Escapes ...	40,000
TOTAL ...	16,80,000

The total cost of the work will then be :—

		Rs.
Earthwork	...	58,00,000
Masonry	...	10,00,000
Escapes	...	17,00,000
TOTAL	...	85,00,000

for 715,000 acres or Rs. 12 per acre. The value of the land will rise from Rs. 500 to Rs. 1,000 per acre, and the resurrection of Central and Western Bengal will have begun. In 40 years the value of agricultural land in Egypt rose from £150,000,000 to £550,000,000. It is to-day £700,000,000.

102. The strip of land some 60 miles long and from 5 to 10 miles wide on the west of the Damodar which is to-day exposed to the floods of the Damodar will be easy to irrigate direct from the River in flood, but I cannot make any propositions here without either levels or the traces of old canals. These canals are necessary if this tract is ever to be protected from malaria and provided with communications. In paras. 73 and 74 of my third lecture I have given my reasons and condemned the re-

moval of long stretches of embankment. The wholesale removal of these banks has raised the bed of the Damodar and done the very thing, to do away with which they were originally intended.

103. We now come to the west and east banks of the Hooghly north of Howrah and Calcutta, on which run the East Indian and Eastern Bengal Railways. Paras. 66 and 67 (*a*) of my third lecture show clearly how malaria, which is everywhere on these banks, started with the construction of these two embankments with insufficient and inadequate culverts for letting river water cross the lines outwards or drainage water cross them coming inwards. All these culverts do not need any regulating apparatus. They only want to be adequate in number and sufficient in size. How for seventy years, embankments are allowed to impoverish lands, and impoverish people and afflict them with malaria, when a trifling expenditure of money could bring relief is a standing source of astonishment in Bengal. When after all these years, these very necessary works are constructed, care should be taken that the channels leading to them and from them are once thoroughly cleaned and then left to the peasantry to maintain.

104. We now come to the canals east of the Hooghly, the land of "dead rivers," which the

pessimists have pronounced to be " already dead, and which can never be reconverted into live streams by the action of men " (see para. 91). After having paced the Mathabhanga bed in 1928 and measured its depth below ground and seen the Ganges in February flowing freely down the Bhairab Jelingi, I saw in vision all these canals full of life as I recounted in my lecture of the 6th March, 1928; but this year I have stood with Khan Bahadur Aziz-el-Haque of Nadia District on Mount Pisgah and seen the promised land. The shift of the channel of the Ganges which had in 1927-28 filled the Mathabhanga in flood and the Bhairab head of the Jelingi with winter and summer water has continued till now and the Districts of Murshidabad and Nadia have begun to use these old canals and are finding them as full of life as ever they were. The Ganges bed has only to be fixed as it is now before it shifts again, and the flood supplies of the Hooghly and all the " dead rivers " to the last most insignificant one of them, will be again utilised. I call upon you Bengalis never to rest and never to let the irrigation service rest till you have secured the fixing of the bed of the Ganges in its present most favourable position. It might cost millions to bring it back if it changed its course and flowed again under Rampur-Boalia.

105. The old irrigation of the sandy tracts which constitute by far the greater part of the districts of Murshidabad and Nadia was well suited to such tracts. The "aus" rice was off the ground by August and then the banks were cut and the old canals miscalled "dead rivers" were opened on to the fields of stubble, covering the ground with plentiful supplies and filling deep all "bhils" and low depressions and thoroughly saturating the ground. It was a kind of late basin irrigation of Egypt, and was followed, as over great part of Egypt, by winter crops of legumins. These winter crops were especially valuable. The peasantry are looking forward to a return of the old prosperous days when irrigation with the muddy water of the Ganges flood was the heritage of all. I have been three times through Nadia and once through Murshidabad by railway in day time, and along the whole length of the Ganges in a steamer, getting out and examining every place worth examining. To see the head of the Mathabhanga we had to walk 17 miles and then get back 17 miles in a bullock cart. A metalled road should be made to the head of the largest irrigation canal in the whole world. With Mr. Inglis' atlas before me, and with the aid of engineers who have been familiar with the ground for years I have

been able to go over the districts one by one. It is very easy to follow the old irrigation canals and understand how the country was irrigated. The irrigation of the country east of the Hooghly must always have been on the broad lines laid down for Nadia and Murshidabad. The areas were too large and the canals on a scale far too great to permit of the delicate irrigation on the east of the Damodar. The early "aus" rice was off the ground about the beginning of August, and the wholesale irrigation of the ground by the numerous canals was begun in imitation of the basin irrigation of Egypt. In an Egyptian basin to-day anyone may grow any crop he likes in summer, but on the 20th of August, the Nile is opened into the basin, and any man who has not removed his crop loses it.

106. In Central Bengal there are so many canals existing on the ground in a workable condition that the expenditure on earthwork will not be great. It will be confined to the lengths of canal which have been ploughed up. These are most numerous in Murshidabad and then in Nadia. The canals in Jessore and Khulna have been left very much alone. If we reckon by the acres of land on which the canals have been obliterated we may put down for earthwork in Murshidabad—

		Rs.
Earthwork in Murshidabad	...	15,00,000
Nadia	...	10,00,000
24-Parganas	...	5,00,000
TOTAL	...	30,00,000
Contingencies $\frac{1}{3}$	...	10,00,000
TOTAL	...	40,00,000

We now come to Regulators. As we have to provide regulators at the heads of every canal which takes off the head of the Bhagirathi or the Ganges in sandy soil, and the canals irrigate large areas the provision must be liberal. Canals such as the Gobra Nala and the Sealmari which take off the Ganges will need headworks which will cost Rs. 3,00,000 each, while ten smaller canals may be credited with Rs. 50,000 each. The Bhairab-Jelingi and the Mathabhanga will need no headworks. They escape into the Hooghly or the Gorai. In the interior of the system, the Regulator on the Mathabhanga downstream of the Churni Head will cost Rs. 10,00,000 and that on the Churni Head will cost Rs. 20,00,000. This will be the Escape into the Hooghly. The Kumar, which escapes into the

Gorai, will need a Regulator costing Rs. 5,00,000. Let it be always remembered that no water is ever escaped into the Gorai if it can possibly be avoided, but that it is escaped into the Hooghly. The Mathabhanga is the true ridge of the country from the Ganges to the sea. Moreover as some canals in the interior of the system seem capable of taking more than their fair share of water, I shall make a provision of Rs. 2,00,000 for each of 5 heads. We have therefore for masonry works :—

		Rs.
2 Regulators at Rs. 3,00,000	...	6,00,000
10 ,, at Rs. 50,000	...	5,00,000
1 Regulator	...	10,00,000
1 ,,	...	20,00,000
1 ,,	...	5,00,000
5 Regulators at Rs. 2,00,000	...	10,00,000
TOTAL	...	56,00,000
Contingencies ⅓	...	17,00,000
TOTAL	...	75,00,000
We have therefore Earthwork	...	40,00,000
Masonry Works	...	75,00,000
TOTAL	...	1,15,00,000

Multiplying by 2, which is my invariable practice for preliminary estimates of this type, we have a total of Rs. 2,30,00,000. This on 5,000,000 acres represents Rs. 4·6 per acre.

In old days they used to sink boats laden with bricks and stone, at the heads of big canals in order to regulate on them, but an engineer can only propose masonry works for canal heads of any importance.

107. When I first saw Bernier's map of what Central Bengal looked like in flood time, I wondered how people could grow rice in the midst of inundations such as he shows, but it is evident that Bernier traversed the country in boats when the "aus" rice was off the ground and the banks had been cut and the whole country was under water. I know about the special rice on the Brahmaputra, but we are not on the Brahmaputra. How thorough this inundation can be will be realized when we can contemplate the Gobra Nala flowing across Murshidabad, irrigating on both sides, mingling its waters with those of the Jelingi, crossing it on the level, and flowing on over Nadia. This is irrigation which will renew the face of the earth. We may expect

in a reasonable time to see the value of land in Central Bengal rise as follows :—

		Rs.
Murshidabad	from 150 Rs. per acre to	300
Nadia	from 150 ,, ,, ,, ,,	300
Jessore	from 100 ,, ,, ,, ,,	300
Khulna	from 200 ,, ,, ,, ,,	400
24-Parganas	from 200 ,, ,, ,, ,,	300

108. We come now to the training and fixing of the Ganges. In paragraphs 76, 77 and 78 of my third lecture I have laid down the lines on which I propose to work. Canals liable to silt cannot carry the coarse sand of the deep waters of rivers, but they are perfectly happy with the finer sediment of the upper waters. If the river bank is not protected upstream of a weak canal head, and a current sets on the bank and brings it down, all the earth which falls into the river makes the water full of silt as it passes the canal head, and this silty water settles in the bed of the canal and makes it still weaker. "Be sure of your canal head" was Alexander the Great's motto when he undertook the restoration of the fertility of ancient Babylonia. His first work on the Euphrates was to change the escape of the river from weak soil into good soil. The Escape of his day is the Euphrates of to-day; and when the

barrage across the Euphrates was built, the work was rendered easy by the skill which Alexander had shown in choosing the site of the escape. (This work, by the way, lives a precarious life because the Wali of Bagdad allowed the Barrage to be built, but took the money allotted for the protecting escape for army expenses. In Irak the army was to irrigation what navigation is to irrigation in Bengal.) The clear waters of rivers have a cutting edge compared to what the muddy flood waters have; and, as all the training works are carried out in times of clear water, we may rest assured that if we can get a river happy in its low water channel it will keep there in flood time. That is why skilfully carried out training and protective works are so effective.

109. For protective works on the Ganges, I propose spurs of the kind described in para. 78 and for training works rows of acacia trees attached to long chains moored to wire-meshed sausages full of well burnt and clinkered bricks, the sausages to be 100 feet apart and the trees 10 feet apart. I estimate (under correction), a mile of 5,000 feet of such a training line as costing Rs. 5,000. For protective works I have already, in para. 77, given the cost of a spur as Rs. 75,000. If I had had any experience of training and protective work on the Ganges or seen

anyone who had, I should speak here with certainty; but, letting myself be guided by experience gained elsewhere, I make the following preliminary estimates for protecting and training works at the four sites where something should be done immediately.

		Rs.
(1) At the last or Bishwantpoor head of the Bhagirathi 6 spurs @ Rs. 75,000	=	4,50,000
100 miles of training lines at Rs. 5,000	=	5,00,000
		9,50,000
(2) At the head of the Bhairab-Jelingi 200 miles of training lines at Rs. 5,000	=	10,00,000
(3) At the head of the Mathabhanga 12 spurs at Rs. 75,000	=	9,00,000
(4) At the Gorai Head 2 spurs at Rs. 75,000	=	1,50,000
20 miles of training lines at Rs. 5,000	=	1,00,000
		2,50,000

This would give a total expenditure of Rs. 31,00,000. All this sounds very expensive, but if you do nothing for 70 years, you cannot expect to be in the position of a man who has worked on steadily from the beginning. I repeat here what I have already said in para. 104 : " I call on you Bengalis never to rest and never to let the irrigation service rest till you have secured the fixing of the bed of the Ganges in its present most favourable position."

110. The very preliminary estimates put before you for restoring irrigation to the tracts which enjoyed it in old days and from which it has been deprived for 70 years and over amount to—

	Earthwork.	Masonry Works, etc.	Total.
	Rs.	Rs	Rs.
Western Bengal	58,00,000	27,00,000	85,00,000
Central Bengal	80,00,000	1,50,00,000	2,30,00,000
Ganges Works	......	31,00,000	31,00,000
Total Rs.	1,38,00,000	2,08,00,000	3,46,00,000

Of these, the Ganges training works and the masonry works should be carried out at once, and the earthwork follow them as quickly as it conveniently can. How these works are to be financed is not the busi-

ness of the engineer, but I can tell you how our works in Egypt were financed when Egypt was practically bankrupt and not allowed to borrow money. The only tax which Lord Cromer was able to touch was the tobacco tax and he raised it. The raising of the tobacco tax saved Egypt. If it had not been for this tax the British occupation would have come to an end before we had a chance of carrying out any of the works which changed the face of the country. The works we carried out soon paid for themselves and provided funds for future works; but, without the tobacco tax, the works could not have been started at all. When I had completed the plans and estimates of the Aswan dam for storing water and the Assiout barrage on the Nile for utilising it, Lord Cromer told me that he was afraid I should never see the works built in my life as the treasury was practically empty and every penny of future savings pledged to the re-conquest of the Sudan. Within a year of this, Sir Ernest Cassel, the London financier, came to Egpyt and offered to build both the works, and hand them over to the Egyptian Government. For five years after the works were completed the interest would accumulate and then he would be paid in 50 years. He is being paid for his works now. Within six months

of the completion of the works, the price of land in Egypt rose from 14 years' purchase to 20 years' purchase, or by 40 per cent., because the Reservoir insured the cotton crop.

111. What happened in Egypt would happen in Bengal if reliable final projects were prepared by men who believed in the irrigation of Bengal and in whom the financial world had confidence. The big financiers of the world are spoiling for big projects and here is the beginning of a very big project. What succeeds on 7 million acres of Bengal will succeed on 5 times that area. An irrigation system which answered for over 2,000 years in Bengal and which was based on Egyptian practice which has answered for 6,000 years in Egypt is one which can be depended on.

112. If these canals are to do their duty as they used to do it before the Mahratta-Afghan wars disorganized everything, the landowners and peasantry must first put their subsidiary water-courses and tanks into good working order, and then clean the canals annually and repair the banks with the material taken out of the canal beds. This work is known as "pulbandi" in Bengal and has been already mentioned in para. 83 of the third lecture. As noted in this paragraph, a cess per acre

is 100 times fairer than personal service and far more effective. For the first 3 years, the peasantry will be quite unable to help in any way as their hands will be full of the work of cleaning and re-newing their tanks and restoring all their old water-courses. Here the co-operative societies should concentrate their attention on this work being done in a spirit of good fellowship animated by the team-spirit.

113. As the irrigation canals have all worked for thousands of years, they have rights over all the railways and roads which are children of yesterday. They also have navigation rights of thousands of years' standing, for the villages are all clustered on the canal banks, and wherever a country boat can go there you invariably see one to-day. In old days they were the only means of communication in flood time. The roads and railways, where they have crossed canals without allowing sufficient waterway, must provide the waterway, or, in the case of roads make paved crossings and use ferries in flood. Along the whole length of the Euphrates, it was so in my time and I believe it is still the same, the river was always crossed by bridges of boats in low supply and by ferries in flood time. There was a little delay, but I never remember

having seen difficulties anywhere. In the basins of Egypt, full of populous and well-to-do villages, all communications in flood time are by boat to-day, and have been so, for 6,000 years.

114. The Hooghly can only be permanently supplied with the water which is essential to its existence as a navigable river for large steamers, if the Ganges is trained and an end put to the vagaries of the river. I have described the utterly disorganized state of its Bhagirathi head in paras. 17 and 18 of my lecture of the 6th March, 1928. When I saw it, it was distinctly a decaying river. And to-day the Hooghly owes its existence as a river to the vigorous canals which are styled "dead rivers." These vigorous canals have been given a new lease of life by the shift in the channel of the Ganges which was so pronounced in 1927, and which made such an impression on me in the winter of 1927-28. Calcutta depends far more on the fixing for ever of this very favourable position of the Ganges than is imagined by those who spend their time on the tidal reaches of the Hooghly and apparently forget that the key of the situation is on the Ganges. All the streams which feed the Bhagirathi and Hooghly on their western bank are insignificant sources of supply. The only reliable sources lie on the Ganges;

and, when the plains of Murshidabad and Nadia are inundated with flood water, and this water, freed of all its sediment, is escaped into the Hooghly, the Hooghly will see a kind of clear water with a cutting edge which it saw in old days but to which it has long been a stranger.

115. All waterways which cut clean across the drainage of an irrigated tract are anathema to the irrigation engineer. Such waterways, if broad and deep, blast the land along their courses. Thank God that western coastal canal which cut clean across the drainage of the whole of Western Bengal has been abandoned. Of the Eastern Sunderban route I repeat what I recorded in para. 59 of my third lecture :—"The Sunderbans have many passages, and except in that at the extreme western end the pilots of the steamers select the one they find most suitable for any particular time of the year." The true Sunderban route, which cuts across no drainage is the route marked out by nature for navigation. "All that is needed at the western end is skill and perseverance or a return to the old state of affairs when the flow of water in and out of so many tidal basins was not interfered with." A return to the old state of affairs at the tidal basin of Diamond Harbour and elsewhere would not only

put the Sunderban route on its legs but would distinctly benefit the Hooghly by restoring to it one of its former tidal basins, of which it ought never to have been deprived. "On rivers serving industrial areas, no works should be executed which definitely tend to obstruct the free flow of the tide." (Marine Works by E. Latham, pages 120 and 121.)

116. Of all the things I have said, there must be many which you will forget; but I beseech you not to forget what I am now going to say. In paragraph 86 of my third lecture I have said:—"The annual measurement of irrigated fields and payment for individual irrigation is the mildew which blasts irrigation in Bengal to-day." It equally blasts irrigation in the Central Provinces and in Bundelkhand, and in many another locality. I ask you to read carefully all I said in paras. 86 and 87. Egypt has the most perfect system of land and irrigation taxation in the world. It has lasted for 6,000 years, and is working as perfectly to-day in perennially irrigated tracts as it has worked in the basins for these many thousands of years. (Here I speak with direct knowledge, because I was Director-General of Land Tax Adjustment in Egypt, which fixed the land and irrigation tax of the country for 30 years.) It is copied in many countries with-

out their knowing of it. If Bengal wants to have a peasantry, prosperous, free of malaria, and free of the worry of watching winds and clouds and who secure bumper harvests every year, let the land and irrigation tax be a single tax. Until that is done you will make no progress. I have travelled in Canada and the States, in North and South Africa and in Europe and Asia, in the interest of my profession, and I know what I am speaking about, and I press my acquired information on you in the most solemn way I can.

117. When flood irrigation has been secured to Central and Western Bengal, it will be time to think of reservoirs in the catchment basin of the Damodar for the provision of October and winter water to the lands between the Damodar and the Hooghly in place of the water which they have been deprived of.

118. I thank H. E. the Governor and the University of Calcutta for letting me, in my own way, help on the cause of Irrigation in India; India, the country in which I was born, where I spent the first 30 years of my life, and which I have always loved. I thank you Miss McLeod and your English friends for bringing me here. May God richly bless your devoted service to the cause of Bengal. I thank Dr. Bentley and all the officials who enabled me to ful-

fil my mission. And finally I thank Dr. Mitra of the Central Co-operative Anti-Malarial Society, Mr. Nandi, District Engineer, Hooghly, and Dr. Ganguli, District Health Officer of Hooghly, who insured the success of week's work among the peasantry. Lord Cromer was right when he told us that if one wished to know the wants of a country, it was the peasantry to whom one should go. By acting on his advice I have been enabled to give you a vision of the ancient irrigation of Bengal which I could not have done if I had spent a lifetime in Bengal, without seeing the peasantry informally in their homes.

118 (*a*). During the week I spent on the long lines of filthy pools, on both sides of which are clustered the decayed homes of the peasantry stricken with malaria, it was difficult to realize that 70 years ago these had been broad streams of living water teeming with fish, on whose banks had clustered prosperous and healthy villages. I asked a friend to let me know the amount of money spent annually on the maintenance of irrigation in Bengal. He told me that making the best use of published figures, and leaving out the cost of establishment, we might say that in recent years the proportions spent on works were

for	Irrigation	7	per cent.
	River banks	36	,, ,,
	Navigation	57	,, ,,

Cinderella is to-day sitting in ashes, but her day is at hand.

119. The task before us is the restoration of the ancient irrigation of Bengal in our day. There is nothing under heaven that can be done to bring back the days when travellers considered Central Bengal as rich as Egypt and the Burdwan Raj as claiming first rank in productive agricultural value in the whole of India, I say, there is nothing that can be done except the reintroduction of the ancient irrigation of Bengal which was definitely given up by the Irrigation Department 70 years ago.

120. That the ancient irrigation of Bengal is alone capable of bringing back the old prosperity of the country is amply borne out by what has happened in the last seventy years. The Irrigation Department has tried its hand at every kind of irrigation except the ancient irrigation. The resulting poverty of soil, destruction of fish, introduction of malaria and congestion of the rivers have stalked the canals and banks; and the country is strewn to-day with the wrecks of useless and harmful works.

Let a return be made to the ancient irrigation of Bengal; and the country will be touched as with a magician's wand, and your ancient prosperity will be at your very doors. This will be so because the ancient irrigation of Bengal was *flood* irrigation and not perennial irrigation, as I have shown in para. 32 of my second lecture. Your very rivers are rousing you to action. The Ganges has wearied of the engineers doing nothing to train it and has trained itself. It has put life into its old water-ways. Take its action as a summons from Heaven, enter upon your rich heritage of well aligned and well placed canals, and may God be with you in all you do.

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